Estimated Abundance of Adult Fall Chum Salmon in the Middle Yukon River, Alaska, 2003

Alaska Fisheries Technical Report Number 71

by

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Key words: fall chum salmon, *Oncorhynchus keta*, mark-recapture, Darroch, population estimate, selective sampling, Yukon River, fish wheel, tag, video

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May 2004

Disclaimers

The U.S. Fish and Wildlife Service, Office of Subsistence Management, provided funding support for this project through the Fisheries Resource Monitoring Program, under agreement numbers 01-032 and 01-177.

The correct citation for this report is:

Apodaca, C. K. , T. J. Underwood, J. F. Bromaghin, and D. W. Daum. 2004. Estimated abundance of adult fall chum salmon in the middle Yukon River, Alaska, 2003. U.S. Fish and Wildlife Service, Fairbanks Fish and Wildlife Field Office, Alaska Fisheries Technical Report 71, Fairbanks, Alaska.

Abstract

Mark and recapture data were collected to estimate the abundance of fall chum salmon *Oncorhynchus keta* during 2003 in the middle Yukon River, above the Tanana River confluence. A seasonal abundance estimate and weekly stratum estimates of migrating fall chum salmon were generated for a period of approximately eight weeks between 28 July and 18 September 2003. Fish were captured using two fish wheels for marking and one fish wheel for recovery. The mark and recovery sites were separated by a distance of 52 km. Spaghetti tags were applied to 5,532 fish at the marking sites. Throughout the season, 35,138 fish were examined for marks at the recovery site, the tag status of 369 of these fish could not be determined and 422 of these fish were recaptured with color-coded tags. Using a Darroch estimator, the estimated abundance of fall chum salmon migrating through the mainstem of the Yukon River in 2003 was 485,102 (SE 25,737). Comparisons of our estimate and run reconstructions, with data from other projects, indicated that our estimate was approximately 16.4% higher than the combined figure for tributary escapement (Chandalar, Sheenjek, and Fishing Branch rivers), harvest above the study area (average of previous five years), and Canadian border passage of fall chum salmon. In addition to producing in-season and annual estimates during the past couple years, we have also focused on identifying factors that increase the potential impact our project has on captured fall chum salmon. As a result, we have worked to improve our protocol to reduce the effect we have on captured fish by: (1) upgrading the quality of fish wheel materials (padding on and around chute and netting on the baskets); (2) reducing the amount of time fish are held in nets and in the fish wheel live-box before and after they are marked; and (3) switching to a video recovery system. This field season was the first time that we completely switched to video recapture and eliminated holding at both the marking and recovery sites throughout the season.

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Introduction

Since 1996, the U.S. Fish and Wildlife Service has generated weekly in-season and annual estimates of adult fall chum salmon *Oncorhynchus keta* abundance in the middle Yukon River, above the Tanana River confluence. The tagging project is designed as a two-event, temporally stratified mark-recapture experiment. During the first two years of the study we established that the Darroch (1961) estimator could be successfully applied in the conditions found on the Yukon River (Gordon et al. 1998; Underwood et al. 2000a), and have used the Darroch estimator in all following years.

During the past several years, the in-season and annual abundance estimates provided by the Rampart-Rapids tagging project have become an important component of the monitoring program for Yukon River fall chum salmon (JTC 2001). Due to low run sizes from 1997 to 2002, Yukon River fishery managers and fishers have become increasingly concerned with in-season management of fall chum salmon. To prevent harvest-related population decline, fishery managers have actively reduced harvest rates throughout the Yukon River drainage by restricting or closing commercial harvest of fall chum salmon and reducing subsistence opportunities when needed. To assess appropriate times to open and close the subsistence fishery, Yukon River fishery managers rely upon available data on run timing and abundance throughout the drainage. The location of the Rampart-Rapids tagging study site makes this project particularly valuable for in-season management of the salmon fishery in the mid and upper regions of the Yukon River.

Through out the course of this project, we have worked to evaluate and reduce our impact on captured fish. In the early years of this study, biologists associated with this project raised concerns about the impact that the Rampart-Rapids tagging study might have on the survivorship of Yukon River fall chum salmon (Underwood et al. In Press**,** Underwood et al. 2002; Burek and Underwood 2002; Bromaghin and Underwood 2003). As a result, during the past few years, we have worked to improve our protocol to reduce the impact we have on captured fish by: (1) upgrading the quality of fish wheel materials (padding on and around chute and netting on the baskets); (2) reducing the amount of time fish are held in nets and in the fish wheel live-box before and after they are marked; and (3) switching to a video recovery system. In previous years of this study, captured fish were held for varying amounts of time in the recovery wheel live-box during hours when the crew was not present (over night and during breaks). Holding also occurred at the marking site, to varying degrees, in all of the previous years of this study. This field season was the first time that we completely switched to video recapture and eliminated holding at both the marking and recovery sites throughout the season. In this report we document the fall chum salmon population estimate generated by the mark-recapture study in 2003.

Study Area

The Yukon River is the fourth largest river basin in North America, with a drainage of more than 855,000 km^2 (Brabets et al. 2000). Three tributaries of the Yukon River, the Koyukuk, Tanana, and Porcupine Rivers are major rivers themselves with drainages of 91,000, 114,737, and 117,000 km^2, respectively (Brabets et al. 2000).

Our study site was located on the mainstem Yukon River 58 km upstream from the Tanana River confluence (Figure 1). The site was selected to minimize capture of fall chum salmon returning to the Tanana River drainage, which constitutes the only known area of substantial fall chum salmon spawning downstream from the study area. The marking site was located at an area known locally as "The Rapids," a narrow canyon 1,176 km from the mouth of the Yukon River. The recapture site was 52 km upstream from the marking site near the village of Rampart, Alaska.

The middle Yukon River, upstream of the Tanana River, is almost 2 km at its widest point and flows at 6 to 12 km per hour. Water height in the middle river fluctuates within and between years (Figure 2). Due to the glacial origins of some of its tributaries, the Yukon River is very silty during the summer but clears during the winter. The region experiences a continental climate with long, cold winters and brief, warm summers. Air temperatures below freezing are common from September through April. Water temperature measured at the south fish wheel (1 meter below surface of water) at the Rapids site in 2003 averaged approximately 14 °C between 16 June and 23 September (Figure 3). The river usually freezes by late October or November, and the ice remains until May of the following year.

Methods

Fish Wheel Schedule and Placement

Under contract with the U.S. Fish and Wildlife Service, Stan Zuray and Paul Evans ran and maintained fish wheels at the marking and recovery sites, respectively, throughout the season. At the marking site, two fish wheels were placed across from each other on the north and south banks of the river (Figure 1). The marking wheels were run as needed to accommodate the marking schedule, from Monday through Saturday each week. A single recovery wheel was run 24 hours a day, seven days a week at the recapture site. The recovery wheel was located near the village of Rampart on the north side of the river (Figure 1).

Fish wheel placement (Figure 4) relative to shore was determined by the depth of the dip on the shoreward edge of the baskets. This edge was positioned to sweep within 30 cm of the bottom. Fish wheels were moved relative to shore as the water level rose or fell to maintain the same proximity to the bottom. A lead, in the form of a submerged picket fence, was placed between the wheel and the shore to direct fish toward the dipping baskets. The river at the marking sites was deeper than at the recapture site, so the fish wheels were sized accordingly. Baskets on the marking wheels are approximately 3.0 m wide and dipped to a depth of 4.5 m below the water surface, and baskets on the recapture fish wheel were approximately 2.5 m wide and dipped 3.0 m below the water surface.

Marking Site Sampling Procedures

Marking took place from 28 July to 18 September 2003, from Monday to Saturday every week, except during the final week (Table 1). To spread capture effort throughout the day, fish were tagged during four daily sessions (0800, 1200, 1600, and 1900 hrs ADT). During each marking session the crew spent an approximately equal amount of time at the north and south wheels. While processing individual fish, we collected information on length and sex, clipped the adipose fin as a secondary mark, and applied an individually numbered and stratum-specific color-coded spaghetti tag (Table 2). Fish length was measured from the middle of the eye to the fork in the caudal fin and recorded to the nearest cm. Sex was determined based on external morphological characteristics. The entire adipose fin was clipped with a pair of scissors, and spaghetti tags were applied through the muscle at the posterior base of the dorsal fin with a hollow applicator needle. After application, the spaghetti tag was knotted within 1.5 cm of the insertion point. All marked fish were captured directly from the chute, tagged, and released back into the river without being held. Fish with major injuries, defined as injuries thought to impede migration, were released without processing. Care was taken to minimize handling time and trauma for all fish captured.

Marking data were recorded via a handheld electronic data logger. Descriptions of data recorded at the marking and recovery sites can be found in Appendix A. Data stored on the handheld data logger were downloaded daily to a laptop computer for processing and storage.

Recapture Site Sampling Procedures

At the recovery site, the fish wheel was run 24 hours a day from 29 July to 21 September 2003 (Table 1), with exceptions for maintenance and fish wheel repair. A video image capture system was installed on the recovery fish wheel using equipment described by Fliris (2001) and Zuray (2001). A camera was mounted above the chute (Figure 4) and video images of fish passing through the chute were captured then sent to a laptop computer using Salmonsoft Fishcap 1.3.4 software. A lightweight door with a magnetic switch was placed at the end of the chute. When the door was opened, the switch tripped and initiated video capture. The video system was set to take 15 video frames per each capture event (six before the trigger event, one during the event, and eight after the event). The crew visited the fish wheel in the morning, afternoon, and evening to back-up files on the laptop and transfer video files to a microdrive for transport to camp. Files were taken back to camp daily for review. Fish were tallied from the video files using review software (Salmonsoft FishRev 1.3.5). Numbers of marked and unmarked chum salmon and tag colors for marked fish were recorded and compiled for each sampling day. All video files were reviewed at least twice during the season.

Analysis of Tagging and Recovery Fish Wheel Data

Travel time.—For travel time analyses, each captured fish was categorized according to the number of strata between marking and recapture. Although we wanted to use only video data for recovery data comparisons, we used crew-generated recovery wheel data for the first week of the 2002 data set because the video system was not running until the second stratum during that season. We did not look at individual travel rates because our tag information in 2003 for recaptured fish is limited to stratum-specific colors.

Abundance estimate.—Following Darroch (1961), the estimate of the number of unmarked fish migrating through our study area, $\hat{n}$, was estimated by:

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

where

a = a vector with elements a_i, the number of tagged fish released in stratum *i*;

C = a matrix with elements c_{ij}, the number of tagged fish released in stratum *i* that were recaptured at the recovery site during recovery stratum *j*; and

b = a vector with elements b_j, the number of untagged fish captured at the recovery site during recovery stratum *j*.

Results

Summary of Tagging and Recovery Fish Wheel Data

In the eight weeks of tagging, 5,532 fall chum salmon were captured and released with uniquely numbered spaghetti tags (Table 3). Of the fish tagged, 168 (3%) were caught twice and 3 (<1%) fish were caught three times at the marking site. An additional 15 (<1%) fish were recaptured with unknown tag numbers. The total proportion of Yukon River fall chum salmon that were recaptured one or more times in the marking wheel was 3.3%. Male fish made up 45% of the overall catch at the marking site, but the percentage of males varied by weekly stratum ranging from 35 to 53%. Lengths for males ranged from 44 to 76 cm and lengths for females ranged from 48 to 71 cm (Table 4). Fall chum salmon captured at the recovery site totaled 35,138, the tag status of 369 of these fish could not be determined, and 422 of these fish were marked recaptures (Table 3).

Analysis of Mark and Recapture Data

Travel time.—In 2003, out of 422 tagged fish that were recaptured, 407 (96%) were recaptured within the same stratum that they were marked, 13 (3%) were recaptured in the following stratum, and 2 (<1%) were captured 2 or more strata later (Figure 5).

Abundance estimate.—Based on eight weeks of mark-recapture data (Table 5), we estimated that 485,102 (SE 25,737) fish passed through the mainstem Yukon River above the Tanana River confluence. Our weekly abundance estimates ranged from 17,891 to 159,118 fish (Table 6).

Discussion

Comparisons of our estimate (485,102; SE 25,737) and run reconstructions, with data from other projects, indicated that our estimate was approximately 16.4% higher than the combined figure for tributary escapement (Chandalar, Sheenjek, and Fishing Branch rivers), harvest above the study area, and Canadian border passage of fall chum salmon (416,911; Table 7). Estimates of subsistence harvests (upstream of the study area within the United States) are not currently available (personal communication, Bill Busher, Alaska Department of Fish and Game), so we used a five year average of subsistence harvest from 1997-2002 (excluding 2000) in place of these values for this comparison. In addition, upriver assessments of abundance have not been finalized as of this writing, so this comparison should be viewed as preliminary. In previous years, our estimates have ranged from approximately 15% lower to 11% higher than run reconstructions.

There are several possible reasons for the differences between our estimate and annual run reconstructions. Past holding practices seem to have led to a tendency for us to underestimate abundance by increasing the probability of recapture at the recovery site (Bromaghin and Underwood 2003). Additional factors that affect these comparisons include: (1) variation between monitoring project schedules and run timing of fall chum salmon; and (2) incomplete coverage of all possible spawning tributaries. The accuracy of these comparisons is also dependent on the reliability of the escapement assessments and subsistence harvest estimates and Canadian border fish passage estimates.

This is the first year that video image capture was exclusively used for tag recovery. When evaluating the potential to switch to video recovery, we carefully weighed the potential positive and negative tradeoffs associated with the proposed change (Underwood et al. 2004). Our primary concerns with switching to video included: (1) losing the ability to identify individual fish using individually numbered tags and associated statistical analysis; (2) decreasing our ability to detect tags, depending on the position and orientation of fish in the video images; and (3) replacing a simple counting system (manual) with one that is dependent on technology in a remote setting (Underwood et al. 2004). The first tradeoff, losing individual tag numbers and associated statistical tests, is an accepted consequence of our efforts to reduce fish handling, reduce the project budget, and simplify the project. Although this is a clear drawback, based on results from previous years (1996-2002), we have no reason to believe that bank-, length-, or sex-related biases has significantly affected our estimates. In years when we witnessed marginally significant effects from any of these factors, we stratified by the potentially biasing factor(s) and never found a significant change in the overall estimate or standard error. To address the second tradeoff, decreased ability to detect tags, we evaluated the number of fish captured at the recovery site with an unknown tag status. Out of 35,048 fall chum salmon observed via video, only 368 (1%) were oriented in a direction that prohibited us from distinguishing whether or not they were marked. This low number of unidentified fish at the recovery site is consistent with the proportion of unidentified fish observed at the recovery site in 2002 (<1% of 5,518 fish; Underwood et al. 2004). As long as the tag status does not influence the orientation of fish on the chute, discarding the data from this small number of fish will not introduce estimation bias but will slightly decrease estimation precision. Finally, the third tradeoff, dependence on technology in a remote setting, was alleviated by the reliability of the video recovery system throughout the season and our ability to deal with wheel maintenance issues in a timely fashion. Throughout the season, the recovery fish wheel stopped due to maintenance, fish wheel damage from debris, and software difficulties for 111 hours, approximately 8% of the total possible running time (1,320 hours) between 29 July and 21 Sept 2003. The recovery fish wheel was stopped on ten different days for an average of approximately 9 hours per stopping session. The days when the wheel was stopped or when we experienced technical difficulties large enough to turn off the video system were spread throughout the season.

Based on our 2002 feasibility study, the perceived benefits of switching to a video recovery effort included: (1) reducing the impact of holding on fall chum salmon captured in the recapture wheel; (2) the potential to reduce the project budget; (3) the addition of a permanent video record of fall chum salmon and other fish species passing through the wheel; and (4) improved the coverage of recovery wheel operations (Underwood et al. 2004). Our recommendation to switch to a video recovery effort was based on the primary interest of reducing our impact on captured fall chum salmon. By eliminating the need to hold or handle fish for prolonged periods, we have met our primary objective. It appears that eliminating holding may have contributed to an overall decrease in the amount of time that it takes marked fish to move between the marking and recovery sites (Bromaghin and Underwood 2003; Figure 5). Although these results are consistent with the results from previous studies that focused on the residual effects of tagging on Yukon River fall chum salmon (Bromaghin and Underwood 2003; Bromaghin et al. In Prep.;Underwood et al. In Press), it should be recognized that several other factors (including changes in water height and various unmeasured biotic and abiotic factors) may influence fish behavior as well. The second objective, reduction of project budget, must be looked at in light of the potential long-term savings. Initially, there are substantial expenses related to start-up costs, however, these expenses may be recouped by savings associated with the reduction of crew size. Overall, the potential to save money is dependent on staffing decisions and the number of years that the project continues to run. The third benefit, creating a permanent video record of all fish species passing through the fish wheel, has made it possible for us to increase our confidence in the recorded data by enabling us to double-check our video observations. All video files were double checked this year. Additionally, having a permanent video record will allow us to begin addressing questions related to migration timing of other fish species in the Yukon River and diel patterns of fish capture.

Due to the relatively low numbers of adult fall chum salmon that returned to the Yukon River in the past 6 years, the resurgence in the population this year was unexpected (Figure 6). The underlying factors that drive population trends for Yukon River salmon are a source of considerable debate. It is difficult to investigate the source of population fluctuations in Yukon River fall chum salmon due to the complex life cycle that is split between marine, brackish, and fresh water environments during different life stages. Several investigators have suggested that climatic shifts influence productivity at sea and in turn have a profound influence on the numbers of Pacific salmon recruits (Beamish et al. 1999; Francis and Hare 1994). Additionally, interactions with hatchery reared fish (Noakes et al. 2000; Meffe 1992) and harvest in both the marine and freshwater environments can have an effect on population trends for some Pacific Salmon species (Ricker 1954). Regardless of the primary factors that affect stock populations returning to the Yukon River, it is important to continue to monitor the population trends of Yukon River fall chum salmon in the freshwater environment. In-season abundance estimates provide mangers with crucial tools to make timely decisions on opening and closing the fall chum salmon fishery throughout the fishing season.

The Rampart-Rapids project provides an in-season abundance estimate of the fall chum salmon aggregate bound for Yukon River tributaries above its confluence with the Tanana River. Both state and federal fisheries managers use the Rampart-Rapids population estimate for making in-season decisions that are time-sensitive and could potentially affect the entire drainage (personal communication, Russ Holder, U.S. Fish and Wildlife Service; Fred Bue, Alaska Department of Fish and Game). Additionally, fisheries managers with ADF&G use the Rampart-Rapids daily catch-per-unit-effort (CPUE) data as an index of run timing to the upper Yukon River. The mainstem abundance estimate has been used in conjunction with the Tanana River abundance estimate to evaluate the run distribution between the two major portions of the drainage and has had a significant influence on management decisions in recent years (personal communication, Fred Bue). Overall, both federal and state fisheries managers utilize our mainstem population estimate and CPUE data for in-season management of fall chum salmon in the middle and upper Yukon River.

Acknowledgments

We would like to recognize the contributions of the seasonal technicians and volunteers including: B. Berkbigler, M. Bushnell, W. Carter, G. Kang, M. LaVoie, G. Maschmann, K. Saylor, T. Spezia, J. Stolarski, F. Walters, A. White, L. Whitman, J. Woods, and K. Zuray. We appreciate Jeff Adams and Ken Russell for their supervisory oversight and administrative support, respectively. We thank Stan Zuray and Paul Evans for operating and maintaining the fish wheels throughout the season and for providing invaluable assistance to the field crews on site. The U.S. Fish and Wildlife Service, Office of Subsistence Management, provided funding support for this project through the Fisheries Resource Monitoring Program, under agreement numbers 01-032 and 01-177.

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Appendix A. Data collected for the Yukon River fall chum salmon tagging project, 2003.

Marking and Recovery Data
Marking Data
Session data
Wheel location
Start month
Start day
Start hour
Start minute
Stop month
Stop day
Stop hour
Stop minute
Number unmarked
Initials of crew member
Fish processing data
Tag number (5-digit)
Recapture code (marked or unmarked)
Fish color (silver, light, dark, unknown)
Fish sex (male, female, unknown)
Fish length
Release time
Recovery Data
Month
Day
Effort (hours)
Number of unmarked fish
Number of marked fish
Tag color of recaptures

Table 1.—Sampling stratum schedule for Yukon River fall chum salmon tagging and recovery efforts, Alaska, 2003.

Stratum	Dates
	Marking site
1	July 28 through Aug 3
2	Aug 4 through Aug 10
3	Aug 11 through Aug 17
4	Aug 18 through Aug 24
5	Aug 25 through Aug 31
6	Sep 1 through Sep 7
7	Sep 8 through Sep 14
8	Sep 15 through Sep 18
	Recapture site
1	July 29 through Aug 4
2	Aug 5 through Aug 11
3	Aug 12 through Aug 18
4	Aug 19 through Aug 25
5	Aug 26 through Sep 1
6	Sep 2 through Sep 8
7	Sep 9 through Sep 15
8	Sep 16 through Sep 21

Table 2.—Color sequence of spaghetti tags used to mark Yukon River fall chum salmon, Rapids study site, Alaska, 2003.

Stratum	Color
1	White
2	Fluorescent green
3	Fluorescent pink
4	Fluorescent yellow
5	Dark green with white band
6	White
7	Fluorescent green
8	Fluorescent pink

Table 3.—Marking and recovery wheel data for Yukon River fall chum salmon captured in Rampart, Alaska, 2003.

Stratum	Marking site	Recovery site		
	Number of tags deployed	Untagged catch	Tagged catch	Tag status unknown
1	230	1,075	14	8
2	423	1,675	34	11
3	375	3,030	24	49
4	755	4,141	43	28
5	671	3,950	36	56
6	1,595	9,536	96	108
7	1,295	8,747	153	99
8	188	2,193	22	10
Total	5,532	34,347	422	369

Table 4.—Summary of sex and length data for Yukon River fall chum salmon tagged and released at the Rapids study site, Alaska, 2003 (F= female and M = male).

Stratum	Sex	Number measured	Proportion within a stratum	Minimum length (cm)	Maximum length (cm)	Mean length (cm)	Standard error of mean length
1	F	107	0.47	51	66	59	0.34
1	M	122	0.53	51	72	62	0.34
2	F	228	0.54	51	69	59	0.23
2	M	195	0.46	50	76	62	0.27
3	F	213	0.57	51	70	59	0.22
3	M	161	0.43	44	71	62	0.33
4	F	395	0.52	50	71	59	0.17
4	M	360	0.48	52	72	62	0.17
5	F	324	0.48	51	67	58	0.16
5	M	347	0.52	52	70	61	0.17
6	F	885	0.55	49	69	59	0.10
6	M	710	0.45	46	74	62	0.13
7	F	788	0.61	48	67	57	0.10
7	M	506	0.39	50	70	61	0.14
8	F	122	0.65	51	64	56	0.23
8	M	66	0.35	52	69	60	0.42

Table 5.—Data sets of Yukon River fall chum salmon marked and recaptured in 2003, and associated counts of unmarked fish with a one day lag time.

		Recapture stratum									
Marking Stratum	**Tags Released**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**	**Fish not captured**
		Recapture data									
1	230	14	5	0	0	0	0	0	0	19	211
2	423	0	29	0	0	0	0	0	0	29	394
3	375	0	0	24	0	0	2	0	0	26	349
4	755	0	0	0	43	2	0	0	0	45	710
5	671	0	0	0	0	34	0	0	0	34	637
6	1,595	0	0	0	0	0	94	5	0	99	1,496
7	1,295	0	0	0	0	0	0	148	1	149	1,146
8	188	0	0	0	0	0	0	0	21	21	167
Total		14	34	24	43	36	96	153	22		5,110
		Unmarked fish captured in the recovery wheel									
Strata 1-8		1,075	1,675	3,030	4,141	3,950	9,536	8,747	2,193		

Table 6.—Stratum and season estimates of abundance, the probability of capture, and associated measures of precision (SE = standard error, CV = coefficients of variation), for the 2003 run of Yukon River fall chum salmon. Dates for weekly strata are based on the marking site strata schedule.

		Abundance			Capture probability		
Stratum	**Date of stratum**	**Estimate**	**SE**	**CV**	**Estimate**	**SE**	**CV**
			Strata estimates				
1	Jul 28-Aug 3	17,891	4,751	0.27	0.013	0.003	0.23
2	Aug 4-10	19,255	4,596	0.24	0.022	0.005	0.23
3	Aug 11-17	47,719	9,702	0.20	0.008	0.002	0.25
4	Aug 18-24	73,463	11,145	0.15	0.010	0.002	0.20
5	Aug 25-Aug 31	74,824	13,070	0.17	0.009	0.002	0.22
6	Sep 1- 7	159,118	16,633	0.10	0.010	0.001	0.10
7	Sep 8-14	73,510	6,313	0.09	0.018	0.002	0.11
8	Sep 15-18	19,321	4,226	0.22	0.011	0.002	0.18
			Season estimate				
1-8	Jul 28-Sep 18	485,102	25,737	0.05			

Table 7.—Comparison of the annual Darroch estimate with measured components of the run (tributary escapement, harvest, and Canadian border passage) upstream of the tagging site from 1996 to 2003, except for 2000.

	Years						
Description	1996	1997	1998	1999	2001	2002	2003
				Escapement projects			
Chandalar River	208,170	199,874	75,811	88,662	110,971	89,847	198,897
Sheenjek River	246,889	80,423[a]	33,058	14,229	53,932	31,856	38,321[b]
Fishing Branch River	77,278	26,959	13,564	12,094	21,635	13,300	24,841[b]
Sum of escapement	532,337	307,256	122,433	114,985	186,538	135,003	262,059[b]
				Border passage			
Mainstem border passage	143,758	94,725	48,047	75,541	38,908	91,808	140,000[c]
				Harvest above the study area			
Rampart	896	646	100	4,324	183	0	[d]
Steven's Village	991	1,585	1,076	20	20	0	[d]
Beaver	9	243	409	16	21	1	[d]
Fort Yukon	8,144	6,119	3,035	9,702	2,209	3,523	[d]
Circle	5,308	3,707	37	2,722	2,588	74	[d]
Central	132	0	0	0	0	0	[d]
Eagle	14,916	14,488	543	11,292	2,714	339	[d]
Chalkytsik	1,230	936	433	442	73	4	[d]
Other	505	421	50	65	0	100	[d]
Sum of harvest	32,131	28,145	5,683	28,583	7,808	4,041	14,852[e]
				Comparison of Rampart-Rapids estimate with the sum of escapement, harvest, and border passage			
Darroch estimate (this project)	654,296	369,547	194,963	189,741	201,766	196,186	485,102
Sum of escapement, sum of harvest[e], and border passage	708,226	430,126	176,163	219,109	233,254	230,852	416,911[e]
Percent difference	-7.6	-14.1	11.0	-13.4	-13.5	-15.1	16.4

[a] Potentially incomplete estimate (personal communication, Bonnie Borba, ADF&G).
[b] This number should be considered a preliminary estimate of harvest pending completion of final project reports (personal communication, Bonnie Borba, ADF&G).
[C] This number should be considered a preliminary estimate of mainstem border passage pending completion of final project reports (Pat Milligan, Canada Department of Fish and Oceans).
[d] Harvest figures not available at time report was written (personal communication, Bill Busher, ADF&G).
[e] Sum of harvest above study area is based on a five-year average from 1997-2002, excluding 2000.

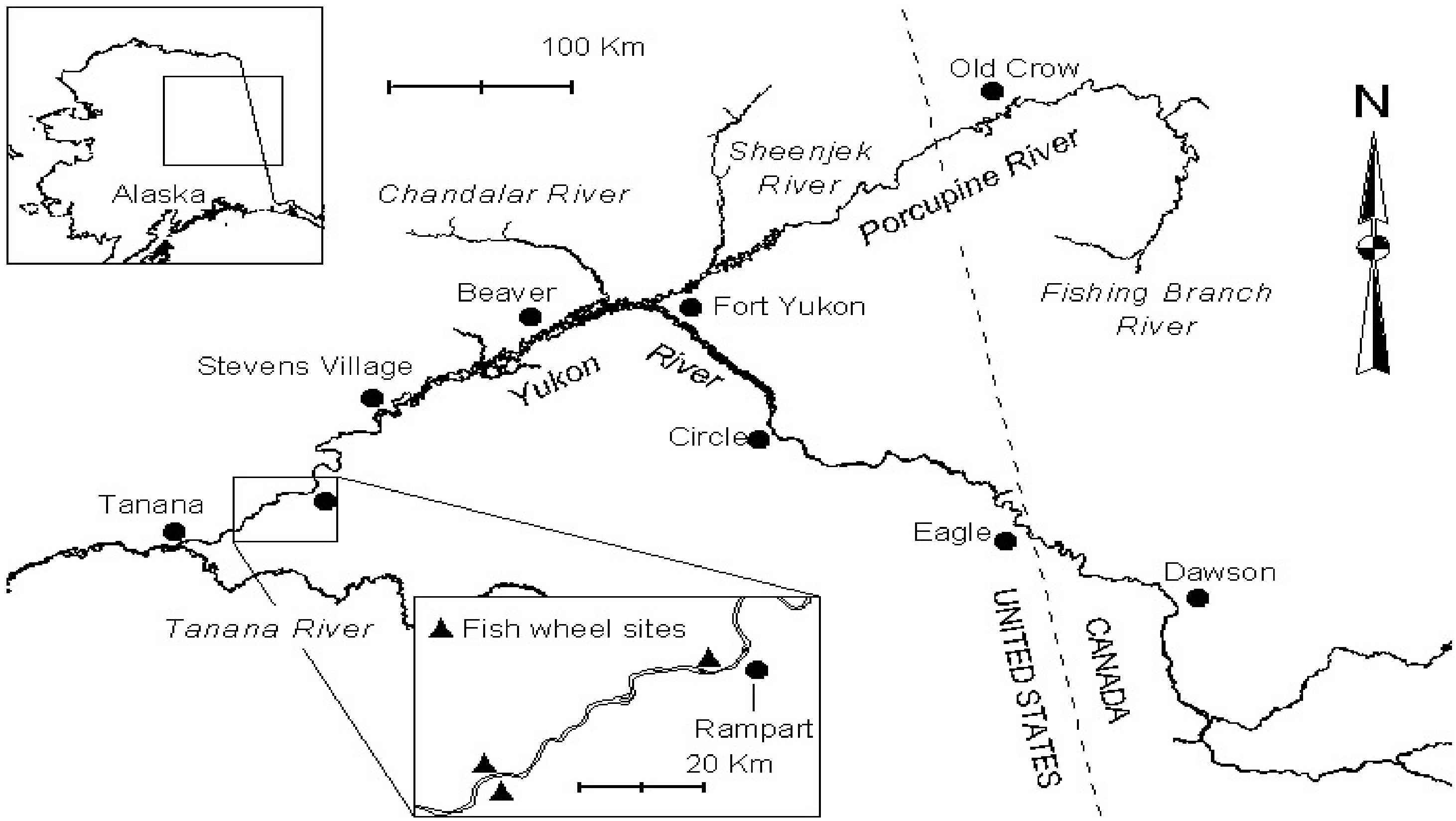

Figure 1.—Map of the Yukon River drainage with an inset of the study area. The marking and recapture fish wheels are indicated with triangles.

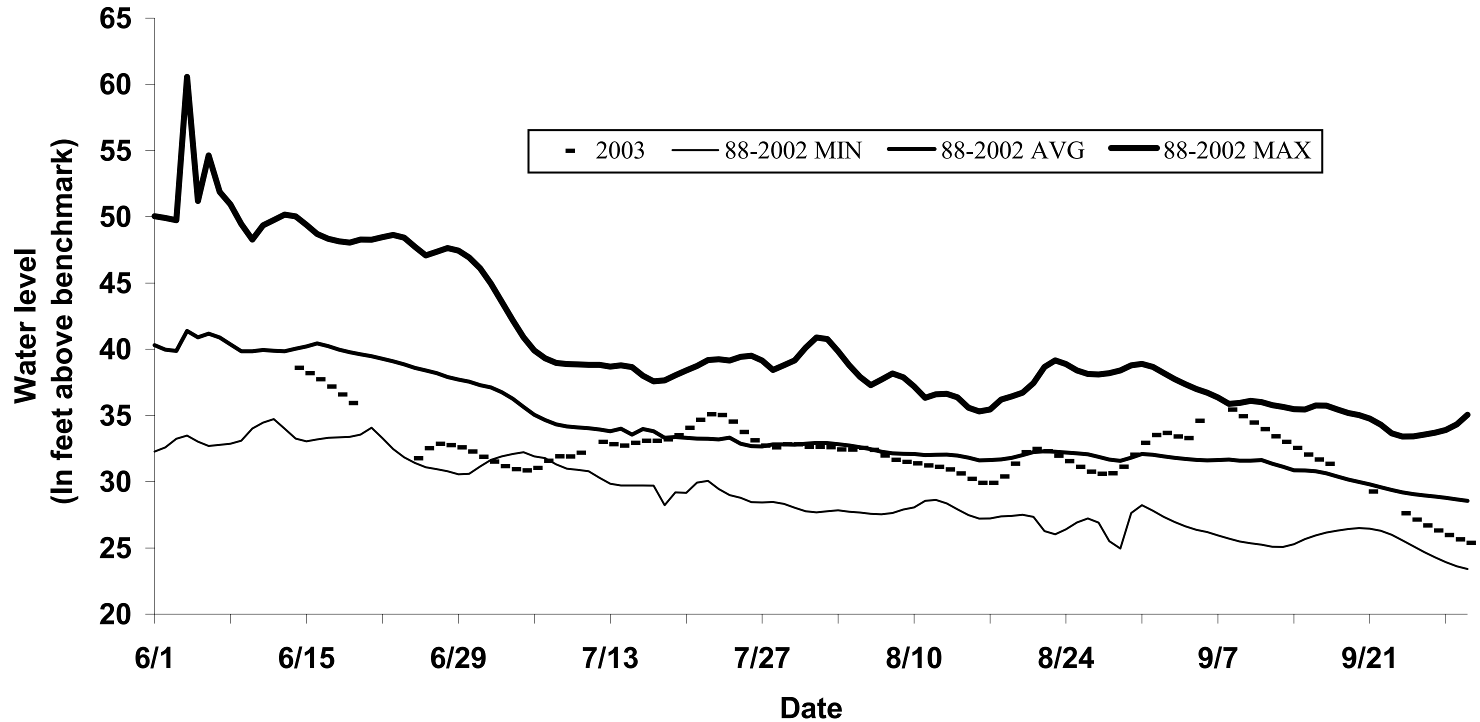

Figure 2.—Average daily water height measured in feet at a fixed USGS gauging station on the Yukon River, near the Dalton Highway. Daily measures are presented for 2003 in comparison with the averages for historical data from 1988-2002.

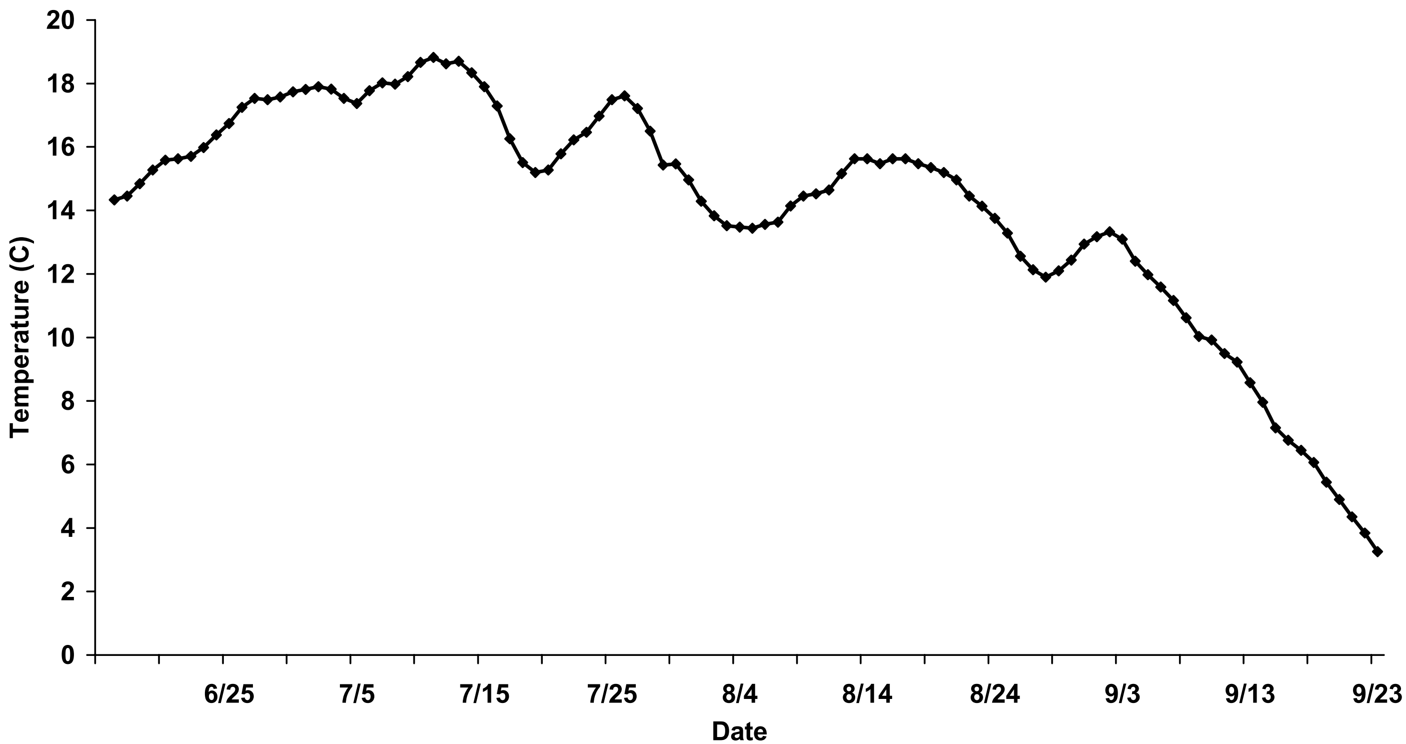

Figure 3.— Average daily water temperature measured with an Onset StowAway TidbiT© water temperature data logger from 16 June to 23 September 2003, Rapids study site, South fish wheel, Alaska.

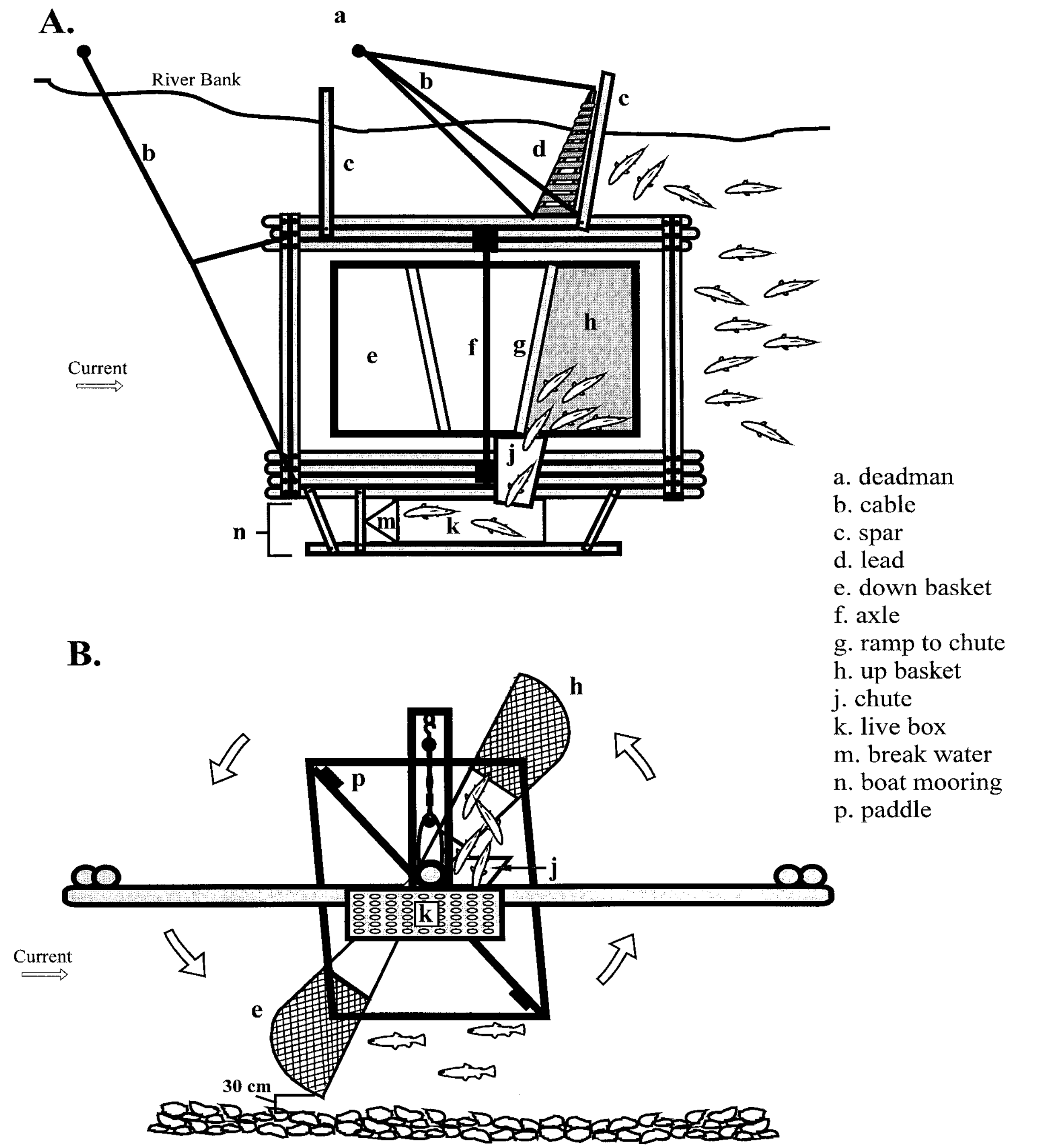

Figure 4.—Two-basket fish wheel equipped with padded chute and live-box used to collect fish during the marking and recapture events. A. Aerial view. B. Side view with arrows indicating the direction of wheel movement in response to the current.

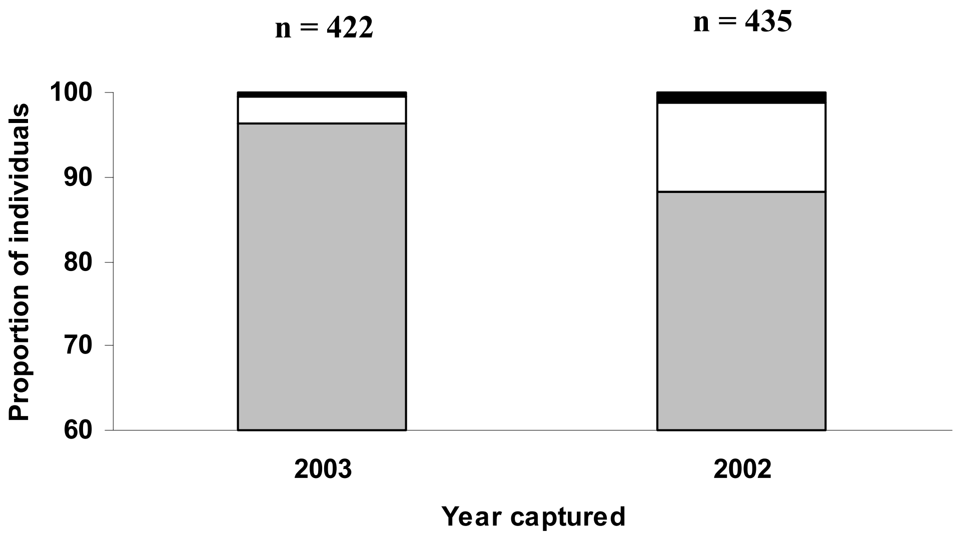

Figure 5—Proportion of Yukon River fall chum salmon recaptured in Rampart, Alaska in 2003 and 2002 within the same stratum that they were marked (gray), recaptured in the stratum following their marking stratum (white), and recaptured in a stratum 2 or more weeks after their marking stratum (black).

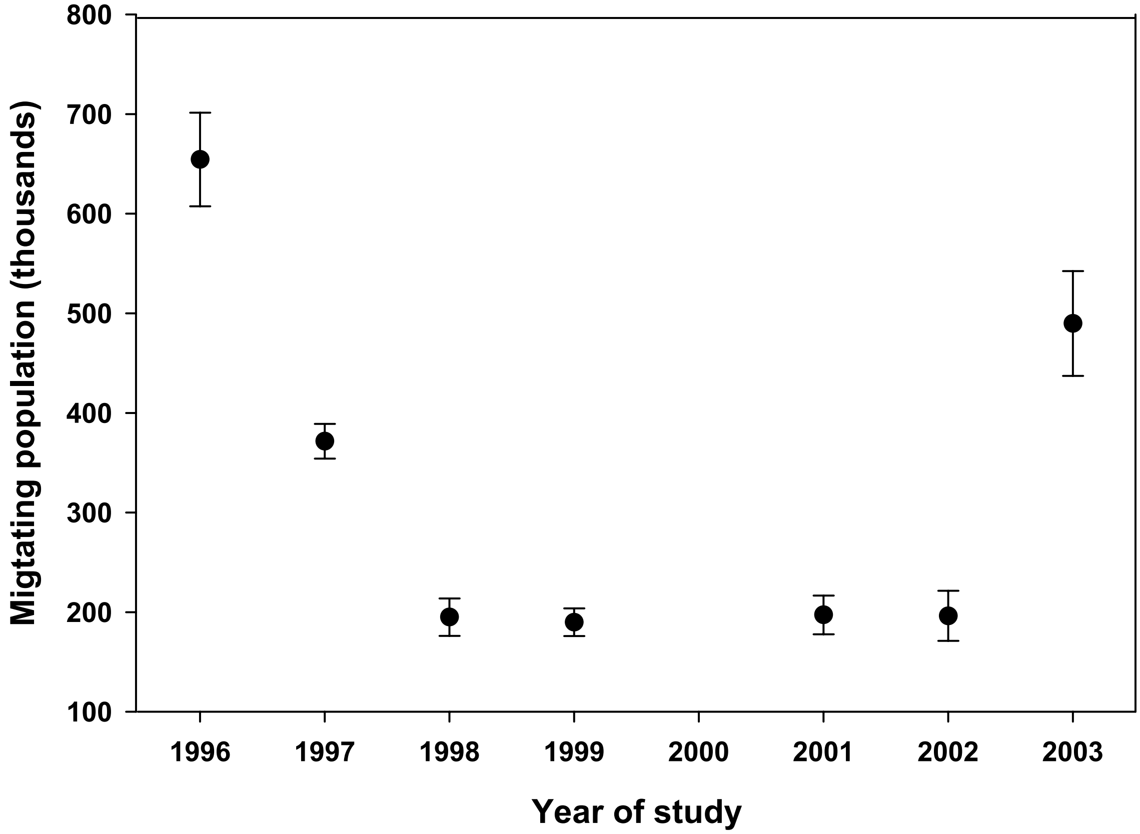

Figure 6.—Population estimates and approximate 95% confidence intervals (2 × SE) at the study site from 1996 to 2003, excluding 2000. A seasonal estimate was not generated in 2000 because the project ran only through the first quartile of the run (historic first quartile based on run timing).