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Abundance of Adult Coho Salmon in the Kenai River, Alaska, 2004

by

Rob Massengill

and

David Evans

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL
Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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By
Rob Massengill
Alaska Department of Fish and Game, Division of Sport Fish, Soldotna
and
David Evans
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Rob Massengill
Alaska Department of Fish and Game, Division of Sport Fish,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669, USA

David Evans,
Alaska Department of Fish and Game, Division of Sport Fish
333 Raspberry Road, Anchorage, AK 99518, USA

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ABSTRACT

A two-event mark-recapture study conducted throughout August and September 2004, produced the sixth consecutive estimate of adult coho salmon abundance in the Kenai River. Two fish wheels were used in the marking event to capture fish near rkm 45. Fish were tagged primarily with spaghetti tags; a sub-sample was radio-tagged and tracked to estimate the portion of all tagged fish that survived tagging and sustained upstream migration. For the recapture event, drift gillnets were deployed from boats between rkm 48.9 and 58.4.

Estimated abundance of adult coho salmon was 118,383 (SE = 9,000). Aggregating this estimate with the estimates representing the number of incidental marking mortalities, the inriver sport harvest downstream from the marking locations, the personal-use harvest, and the UCI commercial harvest allowed for total run reconstruction for 2004 of 184,436 (SE = 13,948). Deducting estimated upstream sport harvest from estimate of live abundance produced an estimate of escapement for 2004 of 95,394 (SE = 9,394). The 2004 harvest rate was estimated as 0.47 (SE = 0.14), and the smolt-to-adult (marine) survival rate was estimated as 0.15 (SE = 0.01).

Estimates of harvest rate for 1999-2004 and recent implementation of additional fishery restrictions suggest that there is no immediate threat to the sustainability of the population or the fisheries it supports and that a harvestable surplus exists most years. Historic information suggests that cumulative fish wheel catch rates may be used to discern weak runs from strong.

Key words: coho salmon, *Oncorhynchus kisutch*, Kenai River, mark-recapture, abundance, escapement, fish wheel, drift net, radio telemetry

INTRODUCTION

Wild coho salmon *Oncorhynchus kisutch* spawn and rear in freshwater drainages of Upper Cook Inlet, Alaska (UCI, Figure 1). As they return to spawn, they are harvested in marine mixed-stock commercial and sport fisheries, as well as freshwater sport and personal-use fisheries. Cook Inlet ranks second in the 1994-2004 mean sport harvest of coho salmon among all regions of theState, sixth in commercial harvest, and fourth in overall harvest (Figure 2).

In 1991, the Alaska Department of Fish and Game (ADF&G) initiated the first program to assess the status of UCI coho salmon stocks (Meyer et al. *Unpublished*). A primary component of the program involved the wild population of coho salmon from the Kenai River, selected because it has consistently supported the largest annual freshwater sport harvest among all Alaskan drainages, accounting for an average one of every six of coho salmon sport harvested in Alaska on average (Mills 1979-1994; Howe et al. 1995-1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, Jennings et al. 2006 a-b, Jennings et al. 2007). The population also contributes to commercial marine fisheries in UCI and, to a lesser degree, to marine sport and inriver personal use fisheries. Despite the substantial harvest, the harvest rate on the Kenai River population was unknown when the assessment program was initiated.

The initial goals of the assessment program were to determine if harvest by existing fisheries was threatening sustained yield and to develop a sustained yield management objective (Meyer et al. *Unpublished*). To achieve these goals, annual estimates of adult production and harvest were needed. A substantial decline in production associated with increasing harvest would signal the need for conservation actions. Furthermore, a sustained yield management objective could be developed from an analysis of the relationship between escapement, total return, and harvest.

The initial research approach was to annually estimate: (A) the population-specific harvest in marine commercial fisheries, (B) the inriver sport and personal-use harvests, and (C) the spawning escapement. The sum of these three components would provide an estimate of annual adult production. The sum of the two harvest components divided by the estimated adult production would provide an estimate of harvest rate.

Commercial harvest estimates (A) have been made annually since 1993 through a coded wire tag (CWT) release and recovery program (Carlon and Hasbrouck 1994 and 1996-1998; Carlon 2000 and 2003; Massengill and Carlon 2005 a, b; Massengill and Carlon 2007 a, b; Massengill *In Prep.* a, b). Inriver sport and personal use harvests (B) have been estimated annually by angler surveys(Mills 1979-1994; Howe et al. 1995-1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, Jennings et al. 2006 a-b, Jennings et al. 2007). Prior to 1999, estimates of total return and spawning escapement (C) were unavailable due to technical limitations of sonar enumeration equipment (Bendock and Vaught 1994). Although a mark-recapture experiment was considered as an alternative method for estimating escapement, the experiment was postponed because of indications that coho salmon are excessively sensitive to handling-induced stress associated with mark-recapture experiments in intertidal zones (Vincent-Lang et al. 1993). Therefore, the total adult return (and harvest rate) remained unknown.

In lieu of adult production and exploitation information, annual smolt production has been monitored as an indicator of the status of the population. Annual smolt estimates are produced as ancillary information in the companion project that estimates commercial harvest. The four earliest smolt estimates (1992-1995) revealed a decline in smolt abundance between the first two estimates (1992-1993) and the second two (1994 and 1995) (Carlon and Clark *Unpublished*). Although the cause was unknown, the decline generated concern for the sustainability of historical harvests. A precautionary management plan was therefore developed and was first in effect during the 1997 fishing season (Alaska Fish and Game Laws and Regulations Annotated, 1997-1998; 5AAC 21.357). A subsequent review of information in 2000 (Clark et al. *Unpublished*) recommended additional precautions in response to a short-term decline in UCI commercial harvests of coho salmon and a more restrictive management plan was developed prior to the 2000 fishing season (Alaska Fish and Game Laws and Regulations Annotated, 2000-2001; 5AAC 21.357).

Unprecedented emergency restrictions to commercial and sport coho salmon fisheries were implemented throughout UCI during the 1997 fishing season. These restrictions were implemented in response to weak commercial harvests early in the season and marine test fishery indications that the overall return to UCI was substantially below average (Ruesch and Fox, 1998). Because the abundance of Cook Inlet populations was unknown, the emergency actions were imposed to protect all populations (including that of the Kenai River) and were more restrictive than specified in the Kenai River Coho Salmon Management Plan. This situation heightened the concern for fishery sustainability, demonstrated the unfavorable nature of managing without quantified objectives, and renewed interest in estimating adult abundance.

Therefore, the feasibility of implementing a mark-recapture experiment to estimate adult abundance was explored in 1998, and annual mark-recapture experiments were implemented in 1999 through 2004. This report documents results of the mark-recapture study in 2004.

OBJECTIVES

The sole objective of the 2004 study was to estimate the abundance of adult coho salmon migrating past rkm 45.

METHODS

STUDY DESIGN

The capture location (Figure 3) was at rkm 45. This tagging location is approximately mid-way between SWHS stratum boundaries. We assumed that about half of the SWHS stratum harvest occurred upstream from tagging location in 2004. The recapture reach was between rkm 48.9 (Funny River tributary confluence) and rkm 58.4.

The tagging event consisted of capturing coho salmon by fish wheels and tagging them with either a spaghetti tag or radio tag daily in August and September. The recapture event consisted of resampling the population primarily with drift gillnets deployed from riverboats over the upstream recapture reach daily from August through early October. Other gear-types such as hook-and-line with artificial lures, and set gillnets were tested experimentally, supplementing drift gillnet catches.

Based on previous studies (Carlon and Evans 2007), a portion of the tagged fish were expected to fail to sustain upstream migration due to capture and handling-induced stress. Ignoring this sampling induced phenomenon would have led to the presumption that more tagged coho salmon were available for recapture than actually were available. The number of tagged fish that became unavailable to recapture was estimated and subtracted from the total number tagged to ensure unbiased estimation of abundance at the fish wheel tagging location.

Radio telemetry was used to determine how many tagged fish succumbed to handling stress. A tacit assumption in this adjustment is that failure to migrate upstream after tagging was due only to handling stress. The assumption is supported by the observed sensitivity of coho salmon to handling and tagging-induced stress in the 1998 feasibility work and other studies (Vincent-Lang et al. 1993). The majority of fish captured in each year's tagging event were tagged with a spaghetti tag while a sub-sample was tagged with a radio tag. Radio-tagged fish were considered surrogates for the spaghetti-tagged sample and their migratory fates relative to the recapture reach were determined through telemetry. The total number of tags released was then adjusted to account for tagged fish that did not migrate upstream or did not sustain upstream migration after tagging.

Because the study objective was to estimate abundance over a two-month period and because tagging and recapture data were collected daily, the study produced two-sample, temporally stratified data. Each tag released in the tagging event was uniquely numbered to permit identification of the date of release and recovery. Various models were tested for their suitability in producing accurate estimates based on such data with computer software (Stratified Population Analysis System Version 1.2, commonly referred to as "SPAS") developed by Arnason et al. (1996). The software automates and enhances standard and accepted analytical procedures first documented by Schaefer (1951) and followed by Chapman and Junge (1956), Darroch (1961), Ricker (1975), Seber (1982), Plante (1990), and Banneheka (1995). The procedure tested the validity of assumptions necessary for accurate estimates from a pooled Lincoln-Petersen estimator ("PPE"). If assumptions of the PPE were fulfilled, the PPE estimate generated by the SPAS software was chosen for its much smaller mean squared error; data pooling provided a much higher degree of precision than the alternatives. If assumptions of the PPE were violated, SPAS was used to produce a maximum-likelihood Darroch estimator of abundance ("ML Darroch" described by Plante [1990]). This estimator is robust to mixing of temporal groups of tagged fish across multiple recapture event temporal strata (see Seber [1982] for example).

Regardless of the model selected, each annual estimate was of the number of live fish migrating upstream of the tagging location in the river. Although the SPAS software does not specifically account for tagging mortality, the application of radio telemetry results to adjust the number of tagged fish provided a *defacto* modification of the procedure. Deducted tagged fish were added to the resultant estimate of fish migrating past the fish wheel to produce an estimate of the number migrating to the tagging location.

The estimated sport harvest from the SWHS occurring upstream of the tagging location was subtracted from the estimated number of live fish migrating past the fish wheel to produce estimated escapement. Estimates of sport, personal-use, and commercial harvest downstream of the tagging location were added to the estimate of the number arriving at the tagging location to produce an estimate of the total return and harvest rate. Estimates of smolt abundance were available from a companion study (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2005 a, b; Massengill and Carlon 2007 a, b; Massengill *In Prep.* a, b), allowing for marine survival to be estimated.

ESTIMATION PROCEDURES AND ASSUMPTION TESTING

A modified Lincoln-Petersen model was used to estimate the abundance of live coho salmon migrating past the tagging location ($\hat{N}$) if model assumptions were satisfied; otherwise, the ML Darroch estimator was used. The Lincoln-Petersen model was modified as follows:

$$\hat{N} = (M\hat{p} + 1)\frac{C+1}{R+1} - 1, \qquad (1)$$

where

M = the number of fish tagged at the tagging location and released,

C = the number of fish examined for marks in the recapture reach,

R = the number of tagged fish recaptured in the recapture reach, and

$\hat{p} = \sum_{i=1}^{L} \phi_i w_i$ the estimated proportion of fish tagged at the tagging location that reestablished and sustained upstream migration after release to at least the mid-point of the recapture reach or were recaptured in the recapture reaach,

where

ϕ_i =proportion of uncensored radio tags that sustained upstream migration in week i,

w_i =proportion of all tagged fish that were tagged in week i,

L = number of weeks over which tagging was conducted,

$M\hat{p}$ = number of tags applied at the fish wheels that sustained upstream migration after tagging and release, and

$\hat{p}$ weights the weekly proportions of uncensored radio tags that sustained upstream migration by the proportion of total marks released each week.

The variable M accounted for the occasional coho salmon that was severely injured or stressed during capture or handling:

$$M = M' - D, \qquad (2)$$

where

M' = the total number of coho salmon tagged, and

D = the number of tagged fish discounted due to injury or stress.

Radio-tagged ish were censored if there was no post-tagging information for the radio-tag, i.e., when a transmitter was never relocated after release. Censored fish were simply disregarded when estimating $\hat{p}$.

The upstream migrants used in calculating the term ϕ_i in the statistic $\hat{p}$ included fish that migrated into the recapture reach, tagged fish that were captured by anglers upstream of the tagging location but downstream of the recapture reach, and fish that sustained upstream migration but favored the Funny River as a spawning destination. We assumed that untagged fish experienced these fates at a similar rate as tagged fish. Upstream migrants that moved downstream immediately after tagging but resumed their migration after a recovery interval were considered as having "sustained upstream migration".

The variance of $\hat{N}$ was estimated from the sample variance of 5,000 simulated estimates of $\hat{N}$ ($\hat{N}^*$, the asterisk denoting a simulated value). For each simulation, each of the $\hat{N}$ fish returning to the tagging location was stochastically assigned to one of the eleven possible fates described in Table 1. The assignment of fish to the eleven fates was made in two parts. The first generated fates for fish not receiving radio tags and the second generated fates for fish receiving radio tags. The simulation required two parts because of the restriction that the number of radio tags applied each year was predetermined and the fish stochastically assigned to radio tag fates (fates 6, 7, 8, 9, and 10) were required to sum to that number (and simultaneously, that the non-radio tagged fish summed to the remainder). The radio tag simulation was also complicated by the fact that $\hat{p}$ in Equation 1 had to be simulated ($\hat{p}^*$) based on weekly fate assignments.

Assignment of the non-radio tagged fish was straightforward and involved simply generating a multinomial random vector of corresponding fates ($f_1^*, f_2^*, f_3^*, f_4^*, f_5^*, f_{11}^*$). Each of the multinomial probabilities used in the generation was calculated as the proportion of the non-radio tagged fish represented by the corresponding fate in the actual data.

In the radio tag simulation, radio tags were assigned by week, with the weekly rate equal to the rate of deployment over weeks in the data. Weekly multinomial random vectors of radio tag fates were generated ($f_{6i}^*, f_{7i}^*, f_{8i}^*, f_{9i}^*, f_{10i}^*$, for week i) with each multinomial probability used in the weekly generation calculated as the proportion of the radio tagged fish represented by the corresponding fate in the associated weekly data. For example, the fate 7 probability for week 4 was calculated as the proportion of radio tags in the data that were deployed in week 4 that met fate 7. The simulated weekly random vectors of radio tag fates were used to calculate weekly simulated upstream migrations (ϕ_i^*) and then simulated $\hat{p}^*$'s. The proportions of total tagged fish by week were not simulated and the w_i from the data were used in calculation of $\hat{p}^*$.

An overall fate vector, representing fates 1 through 11, for each simulation was obtained by combining the non-radio random vector of fates with the radio random vector of fates added over weeks.

Simulated versions of Equation 1 components were calculated for each simulation:

$$M^* = \hat{N} - f_1^* - f_2^*, \tag{3}$$

$$R^* = f_4^* + f_7^*, \tag{4}$$

$$C^* = f_2^* + R^*, \tag{5}$$

$$\hat{p}^* = \sum_{i=1}^{L} \phi^*_i w_i \tag{6}$$

where

$$\phi_i^* = \frac{f_{6i}^* + f_{7i}^* + f_{8i}^*}{f_{6i}^* + f_{7i}^* + f_{8i}^* + f_{10i}^*} \tag{7}$$

$\hat{N}^*$ was then calculated as

$$\hat{N}^* = (M^*\hat{p}^* + 1)\frac{C^* + 1}{R^* + 1} - 1, \tag{8}$$

The estimated variance of $\hat{N}$ was then calculated as the sample variance of the simulated abundance estimates over the 5,000 simulations:

$$V\hat{a}r(\hat{N}) = \frac{\sum_{b=1}^{5000} (\hat{N}_b^* - \overline{N}^*)^2}{4999}, \tag{9}$$

where:

$\overline{N}^*$ = the mean over all simulated estimates $\hat{N}_b^*$.

Seber (1982) outlines the following assumptions necessary for unbiased estimates of abundance (using the modified Lincoln-Petersen model in Equation 1):

1. The population is closed, that is, no additions (recruitment or immigration) or losses (mortality or emigration) occur between sample areas.
2. (a) All coho salmon have an equal probability of capture by fish wheels at the tagging location OR (b) during sampling in the recapture reach OR (c) tagged fish mix completely with untagged fish prior to migrating into the recapture reach.
3. Tagging does not affect capture probability at the recapture reach.
4. Marks (tags) are not lost between sampling events.
5. All tagged fish recaptured in the recapture reach are correctly identified and recorded.

With respect to assumption 1, each year's population of coho salmon was considered closed during the study. Emigration from the mainstem into the Funny River and harvest mortality were assumed to have affected tagged and untagged fish equally. In addition, mortality due to tagging was corrected for using telemetry data ($\hat{p}$ in Equation 1). A small amount of data from the beginning and end of the recapture event was culled to adjust for travel time between the tagging site and the recapture reach. Recaptures of tagged fish (both types of tags) were used to estimate a median time between tagging and vulnerability to capture in the recapture reach. The number of days' data culled from the beginning (c_b) and end (c_e) of the recapture event was calculated as:

$$\begin{aligned} c_b &= u - v \\ c_e &= w - u \end{aligned} \tag{10}$$

where

u = median number of days between tagging and recapture of tagged fish in the recapture reach,

v = number of days between the day on which the first fish (tagged or untagged) was captured in the recapture event and the first day of tagging, and

w = number of days between the day on which the last fish (tagged or untagged) was captured in the recapture event and the last day of tagging.

No days were culled if either c_b or c_e were negative or if recaptures were lost due to culling. Culling days in this manner prevented the inclusion of fish sampled on days during which there was a zero (or very low) probability of recapturing a tagged fish.

With respect to assumption 2, tagging and recapture efforts were scheduled in a consistent manner to maximize the likelihood of homogeneity in capture probability among individuals. Fish wheels were scheduled to operate during the same hours each day over the course of each annual experiment. Drift netting effort was distributed spatially over the entire recapture reach and adjacent to each riverbank. This scheduling tended to equalize the number of drift-netting hours expended in each week and helped to ensure that a similar amount of effort within each hour of the day among weeks was expended. There was approximately a 9 km distance between the tagging and the mid-point of the recovery areas that facilitated mixing of tagged and untagged fish within and between strata.

Despite these procedures, changes in catchability were anticipated over the season due to variable environmental factors such as fish abundance, water depth, velocity, transparency, etc. In addition, mechanical, personnel, and logistical constraints were expected to disrupt the planned distribution of tagging and recapture effort in an unpredictable manner. The three conditions of assumption 2 were assessed with two chi-square tests.

First, we tested the hypothesis that the tagged to untagged ratios were consistent among temporal strata of the recapture event (commonly referred to as the "equal proportions test", Arnason et al. 1996). A non-significant result meant either that probabilities of capture were similar among tagging strata or that movement probabilities from tagging strata to recapture strata were independent of tagging strata, i.e. mixing occurred.

Second, we tested the hypothesis that the ratios of recaptured fish to those not recaptured were consistent among tagging event temporal strata (commonly referred to as the "mixing test", Arnason et al. 1996). A non-significant result meant either that probabilities of capture were similar among recapture strata or that movement probabilities from tagging strata to recapture strata were independent of tagging strata (mixing).

Temporal tagging and recapture strata used in the above tests were generally formed from seven-day periods beginning on the day the first fish was tagged and ending on the last day a fish was captured in the recapture event. If either test produced an insignificant result, then tagging data were pooled over tagging strata and recapture data pooled over recapture strata to provide the pooled Lincoln-Petersen estimate of abundance at the tagging location. It is noted that a non-significant equal proportions test must be accompanied by an assumption regarding identical closure among release strata (Schwarz and Taylor 1998); this assumption is considered reasonable in our study. If both tests produced significant results, the "ML Darroch" model described by Arnason et al. (1996) was used to estimate abundance and its variance. The variability in the estimate of $\hat{p}$ was not incorporated in this variance estimate. This omission is not thought to have affected our results appreciably; a simulation showed the variability induced by our estimation of the proportion of upstream migration to be relatively small.

If the ML Darroch model was selected, tagging and recapture data were stratified as described above. Attempts were made to partially pool recapture and tagging strata to a) overcome numerical problems in estimation, b) overcome inadmissible estimate (e.g. estimates with negative variances, c) overcome significant goodness of fit test results and d) to improve precision while maintaining fit. It was important during the pooling exercise to ensure that we did not remove the original data structure that dictated that we stratify in the first place, i.e. that structure responsible for the significant equal proportions and mixing tests. To this end, the equal proportions and mixing tests were re-examined after each partial pooling scenario to ensure they were still significant. Pooling was subject to constraints that included the relative number of tagging and recapture event strata and putative similarity of within-stratum capture probabilities.

The first pooling constraint was that the number of recapture event strata (t) chosen had to equal or exceed the number of tagging event strata (s). Schwarz and Taylor (1998) point out that under this condition, the stratified abundance estimator is consistent for the population at the tagging site regardless of whether the population is closed between tagging and recapture events. This observation is germane to our study since our objective pertains to the abundance at the tagging site and there is a sport fishery and a spawning location (Funny River) occurring between the tagging and recapture locations. Although we assumed that these conditions did not violate the assumption of closure (as previously described), this constraint was applied to ensure robustness of the model. We maximized our ability to meet the second constraint by ensuring that we pooled only adjacent strata, for which probability of capture is more likely to be similar than for strata temporally far apart. We also examined stratum-specific probability of capture estimates from the original stratified data analysis to help with this effort; these comparisons were, however, hindered by low stratum-specific precision of the capture probability estimates.

The first and second "or" conditions of Lincoln-Petersen assumption 2 can also be violated if capture probabilities vary substantially among individuals of different sizes (possibly as a result of gear selectivity in either sampling event). Size-specific variation in capture probability may require stratification of abundance estimates by size to maintain accuracy at the expense of precision. A standard battery of Kolmogorov-Smirnov (KS) two-sample tests was therefore implemented to determine if size selectivity could be detected in either sampling event. Two KS tests were applied to test for heterogeneity of capture probability by size in the tagging and recapture events following procedures outlined in Appendix 1. The combined results of these tests indicated whether size-selective sampling (and thus heterogeneity of capture probability among individuals) occurred and dictated whether size-stratification of the estimate was necessary. If outcomes of the first two KS tests indicated that size-selective sampling occurred in the second event and it was uncertain if it occurred in the first, a third KS test was used to examine the probability of capture (by size) in the first event by comparing the length frequency distribution of fish recaptured to that of all those captured (and measured) in the second event. Regardless of the statistical conclusions about length selectivity drawn from this battery of tests, means and plots of cumulative length distributions were also inspected for meaningful differences to determine if test results may have been simply due to large (or small) sample sizes. Length data collected on dates culled from the recapture event were excluded from length comparisons to synchronize length comparisons with the data used to estimate abundance, i.e., measured fish that were excluded from the dataset used to produce abundance estimates were also excluded from length comparisons. Note that this procedure culls a small number of length measurements only from fish associated with model parameter "C" (fish examined for marks in the recapture event).

Based on the substantial mortality rate detected in the feasibility study in 1998 (Carlon and Evans 2007), it was expected that assumption 3 - that tagging does not affect capture probability in the recapture reach - would be violated. This violation was compensated for primarily by the application of radio tags, allowing estimation of mark-induced mortality ($1-\hat{p}$). Because there was no way to assess whether tagging had more subtle effects on fish behavior , and therefore, probability of capture in the recapture event, sub-lethal effects (if any) were partially compensated for by choosing drift-netting as the primary recapture gear. Drift-netting is an active technique that does not rely solely on fish behavior (as do passive gear types). Even so, an active gear could not compensate for a possible tagging-induced reduction in migratory rate (relative to untagged fish). Such an effect would be expected to increase the probability of capture in the recapture reach (relative to untagged fish). Therefore, sub-lethal, stress-induced effects were minimized by careful, rapid handling and tagging of fish. In addition, artificially and severely injured or stressed fish were excluded from the tagged sample used to estimate live fish abundance, but were accounted for in the estimate of total abundance.

Assumptions 4 and 5 were not tested but were addressed as follows. The tag wound (skin puncture points and discoloration) served as a secondary mark to assess tag loss (assumption 4). Few, if any, tags were expected to be lost because radio transmitters and spaghetti tags used previously on Chinook and coho salmon in the Kenai River were associated with a low (< 1%) tag loss rate (Alexandersdottir and Marsh 1990; Hammarstrom and Hasbrouck 1998, 1999). Anecdotally, no tag loss has been detected in *ad hoc* observations of carcasses at spawning destinations. Assumption 5 was considered fulfilled because the tag types chosen were highly visible and field personnel were instructed in proper data recording procedures.

Several relevant response variables were statistically tested to determine if it was valid to pool radio- and spaghetti-tagged fish. First, a 2x2 contingency table and chi-square statistic were used to test for independence between tag type and recapture rate. Note that this test also provided an indirect method to detect sub-lethal effects on probability of capture; using two tag types in a mark-recapture experiment. A significant difference between recapture rates would suggest a violation of assumption 3 (if recapture rates are different between tag types, one or neither rate represents the probability of capture for the untagged population). Next, a KS test was conducted to test the null hypothesis that the length distributions of radio-tagged coho salmon were similar between those that sustained upstream migration after release and those that did not (a differential by size would invalidate pooling tag types and require size-stratified estimates of $\hat{p}$). Length distributions of radio- and spaghetti-tagged fish were then compared with KS tests. A 2x2 contingency table and chi-square statistic were then used to test for independence between tag type and bank of recapture. Finally, the median number of days between release and recapture was visually inspected for substantial differences between tag types, there were too few radio tag recaptures to perform statistical tests.

A final battery of statistical tests was applied to determine if tagging data could be pooled regardless of the bank of capture. Chi-square tests were used to test the following hypotheses: that bank of initial capture and the tendency to migrate upstream were independent (a necessary condition prior to testing the next three hypotheses; that bank of initial capture and bank of recapture were independent; and that the tagged-to-untagged ratios and bank of capture in the recapture event were independent. The hypothesis that length distributions of fish caught on each bank were not different was tested with two, two-sample KS tests, comparing tagging event lengths for the first test and recapture event lengths for the second test.

Because both tests (described by Arnason et al. 1996) produced significant test statistics for the 2004 study ,the ML Darroch estimator was considered the appropriate estimator to use.

The estimated abundance of the total return to the fish wheel ($\hat{N}_{TF}$) was estimated as:

$$\hat{N}_{TF} = \hat{N} + M(1 - \hat{p}) + D \quad (11)$$

Because the ML Darroch abundance estimate was chosen, the variance of $\hat{N}_{TF}$ was estimated as:

$$\hat{V}(\hat{N}_{TF}) = \hat{V}(\hat{N}) + M^2\hat{V}(\hat{p}) \quad (12)$$

where $\hat{V}(\hat{N})$ was obtained from the SPAS computer output and $\hat{V}(\hat{p})$ was estimated from simulation as described above. The covariance between $\hat{N}$ and $\hat{p}$ was ignored; simulation showed this to be negative and its omission is therefore conservative (estimated variance is biased high).

Total run ($\hat{N}_T$) was estimated as:

$$\hat{N}_T = \hat{N}_{TF} + \hat{H}_{SD} + \hat{H}_C + \hat{H}_P \quad (13)$$

where

H_{SD} = sport harvest of Kenai River coho salmon downstream of tagging location (estimated by Statewide Harvest Survey),

$H_{SD} = H_{SL}$ + ½(H_{SM}), where

> H_{SL} = the Statewide Harvest Survey estimate of the sport harvest occurring In the Kenai River downstream from the Soldotna Bridge and

H_{SM} = the the Statewide Harvest Survey estimate of the sport harvest occurring in the Kenai River between the Soldotna Bridge and its confluence with the Moose River (rkm 58.4).

H_C = commercial harvest of Kenai River coho salmon (estimated by companion coded wire tag project), and

H_P = personal use/subsistence harvest of Kenai River coho salmon (estimated from permit return data),

with

$$\hat{V}(\hat{N}_T) = \hat{V}(\hat{N}_{TF}) + \hat{V}(\hat{H}_{SD}) + \hat{V}(\hat{H}_C) + \hat{V}(\hat{H}_P) \tag{14}$$

where $\hat{V}(\hat{H}_{SD})$ was obtained from the Statewide Harvest Survey and calculated as $\hat{V}(\hat{H}_{SD})$ = $\hat{V}(\hat{H}_{SL}) + 0.5^2\hat{V}(\hat{H}_{SM})$, $\hat{V}(\hat{H}_C)$, $\hat{V}(\hat{H}_C)$ was obtained from the companion coded wire tag project (Carlon and Hasbrouck 1994, 1996-1998; Carlon 2000, 2003; Massengill and Carlon 2005 a, b; Massengill and Carlon 2007 a, b; Massengill and Evans 2007), and $\hat{V}(\hat{H}_P)$ was obtained from the personal use project (Reimer and Sigurdsson 2004, Dunker and Lafferty 2007).

Escapement ($\hat{E}$) was estimated as:

$$\hat{E} = \hat{N}_{TF} - \hat{H}_{SU} \tag{15}$$

where

H_{SU} = sport harvest of Kenai River coho salmon upstream of capture location (estimated by Statewide Harvest Survey)

with

$$\hat{V}(\hat{E}) = \hat{V}(\hat{N}_{TF}) + \hat{V}(\hat{H}_{SU}) \tag{16}$$

Harvest rate (R) was estimate by:

$$R = \frac{\hat{H}_T}{\hat{N}_T} \tag{17}$$

where

$$\hat{H}_T = \hat{H}_{SD} + \hat{H}_{SU} + \hat{H}_C + \hat{H}_p \tag{18}$$

with variance estimated as :

$$\hat{V}(\hat{E}R) = \left[\frac{\hat{H}_T}{\hat{N}_T}\right]^2 \left[\frac{\hat{V}(\hat{H}_T)}{\hat{H}_T^2} + \frac{\hat{V}(\hat{N}_T)}{\hat{N}_T^2} - 2\hat{\rho}\frac{\hat{V}(\hat{H}_T)^{1/2}}{\hat{H}_T}\frac{\hat{V}(\hat{N}_T)^{1/2}}{\hat{N}_T}\right] \tag{19}$$

where $\hat{\rho}$ was an anticipated correlation between the total harvest estimate and the total run; this was calculated as the sample correlation coefficient between the estimate of the total run and the estimate of the total harvest from 1999-2003 and

$$\hat{V}(\hat{H}_T) = \hat{V}(\hat{H}_{SD}) + \hat{V}(\hat{H}_{SU}) + \hat{V}(\hat{H}_C) + \hat{V}(\hat{H}_P) \quad (20)$$

Smolt-to-adult marine survival from year i to year i+1 was estimated as:

$$\hat{S}_i = \frac{\hat{N}_{T_{i+1}}}{\hat{N}_{Smolt_i}} \quad (21)$$

with variance according to Goodman (1960):

$$\hat{V}(\hat{S}_i) = \hat{N}_{T_{i+1}}{}^2 \hat{V}\left[\frac{1}{\hat{N}_{Smolt\,i}}\right] + \left[\frac{1}{\hat{N}_{Smolt\,i}}\right]^2 \hat{V}(\hat{N}_{T\,i+1}) - \hat{V}(\hat{N}_{T\,i+1})\hat{V}\left[\frac{1}{\hat{N}_{Smolt\,i}}\right] \quad (22)$$

where:

$$\hat{V}\left[\frac{1}{\hat{N}_{Smolt\,i}}\right] \approx \frac{1}{\hat{N}^4_{Smolt_i}} \hat{V}(\hat{N}_{Smolt\,i}). \quad (23)$$

CATCH RATE INDEX

The estimated abundances also provided a means with which to evaluate the utility of fish wheel catch rates as an index of coho salmon abundance. The annual catch rate was estimated as:

$$\mathrm{CR} = \sum_{i=1}^{D} \frac{c_i}{h_i} \quad (24)$$

where

c_i = coho salmon catch during day *i*,

h_i = number of hours fish wheels operated during day *i*, and

D = number of days fish wheels operated during the season.

The relationship between CR and abundance over the five years was then evaluated. A relationship between CR and abundance among years might prove to be a useful alternative to the mark-recapture experiment by reducing costs and resource impacts of a mark-recapture experiment.

TAGGING EVENT

Two float-mounted fish wheels were used to capture coho salmon for tagging with one fish wheel installed adjacent to each riverbank. The fish wheels were a standard, two basket/two-paddle design. To address the study assumption of equal probability of capture for all fish, the fish wheels were operated as consistently as possible among days. Fish wheels were frequently adjusted so that the baskets touched or were close to touching the river bottom as much as possible to consistently minimize that escape route. Although the relationship between fish wheel spin rate and catchability is unknown, fish wheels were moved short distances or adjusted to maintain spin rates between about 3 and 4.5 rpm rpm (spin rates lower than 3 appeared ineffective while spin rates greater than 5 were associated with increased injuries to fish). Fish wheels were scheduled to operate a consistent number of hours each day from August 1 through September 30.

Captured coho salmon were processed as quickly as possible. When pink or sockeye salmon catches were overwhelming, fish wheels were stopped while unattended; this occurred occasionally during the last week of August and the first two weeks of September.

The fish wheels were scheduled to operate between the hours of 0630 and 2130 because this period was identified from the 1999 diurnal experiment as the period when over 90% of the coho salmon catch occurred (Carlon and Evans 2007). Fish wheels were not operated during lunch breaks and shift changes.

All captured fish other than coho salmon were identified by species, enumerated, and released. All coho salmon captured were transferred via dip net from the fish wheel trap box into a holding tank filled with river water. A padded restraining device (Larson 1995) was used to hold fish during measuring and tagging. Each fish was tagged with an external spaghetti or radio tag, measured for length (FL) to the nearest 10mm. All coho were then released immediately back into the river without first holding in a livebox for a recovery period. Immediately returning a fish back to the river was identified in earlier studies to improve the survival rate of tagged fish (Carlon and Evans 2007).

Uniquely numbered, 30.5 cm long, Floy FT-4 spaghetti tags were the primary mark used. Tags were applied about 1-2 cm below and 3-4 cm anterior to the posterior insertion of the dorsal fin. Those fish that were artificially injured or stressed during capture were categorized as 'dscounted' and were tagged prior to release with a spaghetti tag so that if recaptured, they could be disregarded. Advanced Telemetry Systems (ATS) radio tags, broadcast in the 151-152 MHz band, were used. Model F2110 tags, measuring about 19 mm by 40 mm by 9 mm and weighing about 14 g, were used. Radio tags were affixed parallel to the insertion of the dorsal fin and immediately below it and secured with a Petersen disk. The attachment devices were two Teflon®-coated, 18-8 braided stainless steel wire ropes measuring 0.8 mm (0.032") in diameter. The same insertion technique and location used in 1999 was employed. However, the transmitters were secured in place using #3 single-barrel, anodized steel fishing leader sleeves crimped onto the cables using lineman's pliers such that the Petersen disk and transmitter were held securely in place. Throughout August and September 122 radio tags were released at a rate of two per day.

The time of day for selecting a fish for radio tagging was randomly selected from ½ hour increments. A size criterion was applied to select fish for radio tagging. During each week of sampling, lengths were collected from all captured coho salmon and the 33rd and 67th percentiles of the prior week's length distribution were used as boundaries to divide the length distribution into three groups (< 33rd percentile, ≥ 33rd percentile and < 67th percentile, and ≤ 67th percentile). As coho salmon were captured, one fish from each of the three length groups was tagged when 3 fish were scheduled for tagging on a given day. Quartiles were used whenever 4 fish were scheduled for tagging and the median was used when 2 were scheduled. If a fish of the proper size was not captured during a randomly scheduled ½-hour period, the next captured fish meeting the size criterion was selected for radio tagging.

Environmental data were recorded daily near the capture site location. Water transparency was measured mid-day to the nearest 0.1m as measured with a standard Secchi disk (Wetzel 1975). Fish wheel rotation in revolutions per minute (rpm) was measured each day by both crews mid-shift. River discharge and gauge height was recorded daily by the USGS at the Soldotna Bridge gaging station 15266300 and was available online at at: http://waterdata.usgs.gov/ak/nwis/uv/ .

RADIO TELEMETRY

Radio tagged fish were relocated with data-recording telemetry stations installed along stream banks (Figure 4), receiver-equipped boats, trucks, and from fixed or rotary wing aircraft. Each relocated fish was assigned a binomial fate relative to the recapture reach: fish either reestablished and sustained upstream migration toward the recapture reach after tagging, or they did not.

RECAPTURE EVENT

Drift gillnets deployed from outboard-powered riverboats were the primary gear to sample the population for marks. Drift gillnet specifications were intended to capture fish by entanglement rather than by wedging fish into a single mesh space permitting fish to be more easily removed upon capture and decreasing injury. Drift gillnets were made to the following specifications: Miracle Brand® type MS-43, knotted multi-strand monofilament with color designation R14. The stretched mesh dimension was 4.75” and nets were 29 meshes deep and 5 fathoms long.

Field personnel attempted to expend drift netting effort along each bank of the river within the recapture reach and along the extent of the reach to ensure that effort was not concentrated in time or space. Previous study results in (Carlon and Evans 2007) indicated that fish tended to migrate in near-shore waters. Therefore, most fishing effort was bank-oriented.

Drift gillnets were deployed almost every day from August 1 through October 5. Drift gillnetting effort was scheduled to distribute effort evenly over each weekly period during the study. As few as two work shifts and as many as four were scheduled on any given day with a total 20 scheduled each week. Possible work shift times included a morning shift (0600-1400 hrs), a mid-day shift (1000-1800 hrs), and an evening shift (1400-2200 hrs). During each week, eight of each of the morning and evening shifts were scheduled and four of the mid-day shifts were scheduled. Hook-and-line sport fishing techniques and set gillnets were also used to a limited extent.

The number of fish captured other than adult coho salmon was recorded and the fish were released. Each coho salmon received a dorsal fin punch with a standard one-hole paper punch to ensure that recapture event sampling was accomplished without replacement. The fish was inspected for the presence of a prior dorsal fin punch and for the presence of a tag or a tag wound indicating tag loss. If a tag wound was present, the type of wound (radio or spaghetti) was recorded. If a tagged fish was captured, the tag type and tag number were recorded. As many recaptured fish as possible were measured as previously described. Whenever possible, the fork-length of all recaptured fish was to be measured. In practice, recaptured fish were not always measured; when not measured, the measurement recorded when the fish was initially tagged was substituted in length selectivity tests. Every 10th newly captured coho salmon was sampled for fork length (FL).

DATA ARCHIVING

A comprehensive list of data files collected during the five annual experiments is contained in Appendix 2. Archived files are managed by the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services Section in Anchorage, Alaska.

RESULTS

Tagging and Recapture Summary

Tagging Event

During the tagging event, river discharge ranged from 4,030 to 17,200 cfs (Figure 5); average discharge was: 10,921. The river stage fluctuated over a range of about 0.98 m and water transparency averaged 0.94 m (Figure 5).

The fish wheels were operated daily from August 1 through September 30 with 1,080 hours of total operation time expended (Table 2). The catch rate averaged 8.57 coho salmon per hour; Table 2). The fish wheels were frequently stopped because of the overwhelming abundance of pink and sockeye salmon resulting in lower than expected fish wheel operation.

9,612 coho salmon were captured. Forty-six escaped handling prior to tagging, 309 were tagged fish that were recaptured in the fish wheels, 5 were injured, four were sacrificed for CWT recovery, and eleven had a fin punch. The remaining 9,237 coho salmon were included in the tagged sample: 122 were tagged with radio tags and 9,115 were tagged with spaghetti tags.

Species other than coho salmon were also captured (Appendix 3). 18,537 sockeye salmon were captured, and about 30,713 pink salmon. Other species included Chinook *O. tshawytscha*, chum *O. keta*, Dolly Varden *Salvelinus malma*, rainbow trout *O. mykiss*, steelhead, and whitefish spp.

Recapture Event

Effort was expended daily in the recapture reach during August 1 through October 5. Distribution of gillnetting effort among river kilometers was relatively even across the recapture reach as was temporal distribution through the day.

Drift gillnetting effort totaled about 254 hours during the recapture event (Table 3). A set gillnet was tested experimentally several times for 1.5 hours of total effort but no coho salmon were caught, and twelve coho salmon were caught with hook-and-line.

A total of 5,172 coho salmon were captured (Table 4). There were 270 instances in which coho salmon (both tagged and untagged) were caught multiple times, and 189 others escaped prior to close examination leaving 4,713 unique fish that were examined for marks. 333 (7.1%) had marks, 2 with radio tags and 331 with spaghetti tags. The exact time of capture and tagging was recorded for all 333 recaptured fish (Appendix 4). The mean time between tagging and recapture for these was 5.3 days over a range of 43 days (minimum of 0.2 days, maximum of 43.2 days).

During the recapture event, over 13,585 pink salmon were captured and 4,018 sockeye salmon were captured. Other species included Chinook, Dolly Varden, rainbow trout/steelhead, whitefish, and longnose sucker (Appendix 5).

Radio Telemetry

In 2004, One hundred twenty two radio tags were released. None were censored although 26 (21%) did not migrate upstream, leaving 96 (79%) that did migrate upstream (Appendix 6). Date and time of entry into the recapture reach was determined for 85 of the upstream migrants. The mean time between tagging and entry into the recapture reach for these fish was 2.9 days over a 24.7-day range (minimum 0.2 days, maximum 24.7 days) with a median of 1.3 days.

EXPERIMENTAL ASSUMPTION TESTS AND ABUNDANCE ESTIMATES

Pooling Data Over Tag Type

Statistical tests indicated that mark-recapture data collected from fish tagged with either tag type (radio or spaghetti) could be pooled. The results of the tests comparing radio and spaghetti tags are as follows:

1. **Recapture Rate**: The recapture rate ranged from 1.6% for radio tags and 3.6% for spaghetti tags, but recapture rates did not differ significantly between tag type (Table 5).
2. **Overall Length Distributions**: Cumulative length distributions of each tag type were similar and no statistical differences were detected (Table 6, Figure 6).
3. **Bank of Recapture**: Testing for independence between tag type and bank of recapture suggest that radio tagged fish distributed between banks after marking and release in a similar fashion as spaghetti tagged fish; no significant differences were detected in the test for independence between tag type and bank of recapture (Table 7).
4. **Length Distributions of Upstream Migration**: There were no significant differences detected in cumulative length distributions between radio-tagged fish that sustained upstream migration after tagging and those that did not (Table 8). Furthermore, there were no significant differences detected between length distributions of radio tagged fish that sustained upstream migration and spaghetti-tagged fish that were recaptured (Table 9).
5. **Travel Time**: The absolute difference between the median duration of marked fish to be recaptured (in the recapture effort) and median days for radio tagged fish to enter the recapture area was 2.1 days (Figure 7 and Figure 8). The difference in median travel time appears inconsequential relative to the study duration and was another indication that both tag types behaved similarly.

The results described in 1-5 above suggested that pooling tag types and considering them as a single mark was appropriate.

Pooling Data Over Banks

Examination of pooled data further suggested that pooling between riverbanks was also appropriate in all years and in both the tagging and recapture events. The test results were as follows:

1. **Upstream Migration**: Tests of the null hypothesis that upstream migration of radio tagged fish was independent of river bank of initial capture were not significant (Table 10).
2. **Recapture Rate**: Testing of the null hypothesis that recapture rates were independent of bank was significant (Table 11). Although significant ($P < .001$), the difference in the proportion of recaptured tags between banks of initial capture was small (0.044 for the north bank versus 0.030 for the south bank).
3. **Length Distribution**: A significant difference in the cumulative length distributions were detected by KS tests for fish tagged on the north bank versus those tagged on the south (Table 12). However, mean fish length differed between banks by less than 4mm mm and cumulative length distributions were similar in shape (Figure 9). This indicates that KS tests likely detected inconsequential differences because sample size provided the power to do so.

4. **Bank to Bank Mixing:** Fish tagged adjacent to either river bank mixed across banks between both events as indicated by the lack of significant results in tests for independence between bank of initial capture and bank of recapture (Table 13).

Further examination of the recapture effort supported the pooling of data across banks. No bank-related differences were detected in the tagged proportions in the samples of fish examined in the recapture event (Table 14), indicating that tagged fish mixed between banks and that the pooling over riverbank was appropriate for the tagging event. Finally, significant differences were detected between bank-specific length distributions of fish captured in the recapture event (Table 15). Again, bank-specific mean lengths and bank-specific cumulative frequency distributions indicated that actual differences were inconsequential (with a maximum difference of 15 mm; Figure 10) despite statistical test results. Therefore, mark and recapture data were pooled across riverbanks.

Proportion Surviving to Sustain Upstream Migration ($\hat{p}$)

A total of 122 fish were tagged with radio tags (Table 16). No fish were censored, and between 79% of the uncensored radio tagged sample survived and sustained upstream migration ("upstreamers") after tagging. After weighting weekly rates of "upstreamers" to account for all marks released each week (radio and spaghetti tags), estimates of the proportion of all tagged fish surviving to sustain upstream migration ($\hat{p}$)was 0.773.

Data Culling and Standard Mark-Recapture Assumption Testing

Two coho salmon were examined on the first 2 days of recapture effort and those days were culled, likewise, untagged fish examined on the last day were culled, representing a total of 16 untagged fish. Of the total sample of coho salmon examined in the study, culled fish represented 0.4%. The "equal proportions" statistical test produced a significant result (Table 17), so we cannot conclude that there was homogeneity in capture probabilities over tagging event strata or that probability of movement to recapture strata was independent of initial capture strata. The "mixing" statistical test also produced a significant result (Table 18), indicating that we cannot conclude homogeneity of capture probabilities in the recapture event nor that probability of movement to recapture strata was independent of initial capture strata.. Because both tests produced significant test statistics, the ML Darroch estimator was considered the appropriate estimator to use.

KS testing indicated there was size selectivity in the marking event but not in the recapture event. Although size-selectivity was detected, it was not detected in both sampling events (Table 19, Figure 11). Therefore, size stratification was not required.

For convenience, a final summary of results and conclusions of the "equal proportions" test, the "mixing" test, and length selectivity test are presented together in Table 20. Temporal stratification schemes and data used to formulate estimates are summarized in Table 21.

ABUNDANCE, TOTAL RUN, HARVEST RATE AND MARINE SURVIVAL

The 2004 abundance at the fish wheel was 120,489 (SE = 9,008) and live abundance was 118,383 (SE = 9,000) coho salmon (Table 22). Sport harvest upstream of the capture location was 22,989 (SE = 2,692), and escapement was 95,394 (SE = 9,374) coho salmon. The total run was 183,875 (SE = 13,948) coho salmon and harvest rate was 0.470 (SE = 0.020). Marine survival (Table 23) was 0.150 (SE = 0.010).

CATCH RATE ABUNDANCE INDEX

The combined fish wheel coho salmon cumulative catch rate was 574.55. A weighted regression using all estimates of abundance (1999-2004) on the corresponding natural log of cumulative catch rates (Table 24, Figure 10) yielded a linear relationship with a positive slope (P = 0.002 for H_o slope = 0; R^2=0.93). The weighted regression was used to account for the fact that the abundance estimates were measured with varying precision for different years (especially relevant for ML Darroch vs. Pooled Petersen methods). The positive linear relationship suggests that cumulative catch rate may be of value in qualitatively discerning small runs from large.

DISCUSSION

IMPLICATIONS OF RESULTS

The 2004 estimate of Kenai River adult coho salmon abundance represents the sixth consecutive abundance estimate (1999-2004) available for this population. These baseline harvest rates provide an indicator of resource and fishery sustainability.

The six escapement estimates provide enough information to develop an escapement goal. Escapement goals for salmon are developed to provide an escapement range that allows a population to be sustained, and in some cases, to maximize the sustainable yield as is the case with a biologic escapement goal (BEG) and therefore provide a rational means for managers to quantify harvestable surpluses. For an escapement goal or threshold to be useful for fishery managers, a mechanism must exist to provide inseason return information. Currently, no mechanism exists for Kenai River coho salmon.

Recent changes to Kenai River adult coho salmon research objectives include discontinuing the estimation of inriver adult abundance (final year in 2004) and commercial harvest (final year in 2005). The objective is to index the inriver abundance into one of three general levels using fish wheel CPUE (begun in 2005). Therefore, pursuing an escapement goal for this population is impractical under current research objectives.

Developing escapement goals that produce maximum sustained yield for coho salmon can be difficult due to atypical spawner-recruit dynamics relative to other salmonids. Shaul (1994) reported spawner-recruit relationships were not possible for some coho salmon indicator stocks in Southeast Alaska. Research suggests that production of coho smolts from freshwater habitats appears strongly limited by the availability of suitable habitat (Chapman 1965; Bradford et al. 1997). Bradford et al. (1999) suggests that juvenile survival is independent of density up to a critical spawner level and that streams can be fully seeded with juveniles at relatively low spawner abundances. The Kenai River adult return in 2003 (135,978 fish) was produced primarily by the low 1999 escapement (~8,000 spawners). The normal 2003 adult return resulting from a relatively low escapement aligns with known population dynamics for other coho stocks exhibiting similar production values indicating coho production is influenced less by escapement (above a minimum threshold level) than by marine survival and freshwater habitat availability.

At a minimum, estimates of harvest rate might provide the best insight into the sustainability of the resource under the current harvest regime. Harvest rate has ranged from 0.35 to 0.84, and has not exceeded 0.47 in five of six study years, and averaged 0.49. By comparison with harvest rates measured in other wild coho salmon populations in Alaska, this level is not considered an immediate threat to the sustainability of the population nor the fisheries. From 1992 through 2002, the Taku River (in Southeast Alaska) experienced harvest rates ranging between 0.28 and 0.72, averaging 0.46 (Shaul et al. 2003.). Average annual harvest rates measured in an aggregate of populations among four other intensively studied indicator streams in Southeast Alaska have ranged between 0.40 and 0.68, averaging 0.59 during the period 1982 through 2002 (Geiger and McPherson 2004). Geiger and McPherson (2004) also reviewed Southeast Alaska populations in general and reported an "excellent overall condition" with no populations of concern identified. In addition, the first two estimates of harvest rate for a wild population that has supported long-term fisheries in northern Cook Inlet (Cottonwood Creek) were 0.47 and 0.29 for 1999 and 2000, respectively, averaging 0.38 (Namtvedt et al. *In prep*). None of these averages is substantially different from the average of the estimates for the Kenai River population and the Southeast Alaska database is extensive enough to conclude that this general level of harvest is at least associated with sustained yield among a wide variety of drainages.

Although the 1999 harvest rate (0.84) was substantially greater than estimated during the other five years, it does not appear that harvest chronically approximates this rate. Precautionary restrictions have limited the harvest potential - and presumably harvest rate to a level below that which has been sustained in persistent and substantial fisheries. This is considered an indirect but complimentary indication that current (restricted) harvest levels are sustainable. Although these observations suggest that there is no immediate threat to sustainability, they also suggest that some components of the management plans in effect during 2004 were unduly restrictive. Moderate harvest rates have been estimated since the full compliment of sport and commercial harvest restrictions was imposed in 2000. The great harvest potential demonstrated in 1994 (121,000 coho salmon), relative to the baseline estimates of total return, and high harvest rate observed in 1999 demonstrates the potential for fisheries to impose excessive exploitation; particularly in the event of a weak return.

During the 1999 through 2004 study period, the estimated abundance at the fish wheel capture locations ranged nearly an order of magnitude, from about 23,000 fish in 1999 to nearly 158,000 in 2002. In addition, netting catch rates in the recapture reach reflected a corresponding difference with 8.8 and 27.3 coho salmon per netting hour during 1999 and 2002, respectively (Carlon and Evans 2007). Fish wheel cumulative catch rates were also indicative of general abundance ranging from nearly 27 units in 1999 to nearly 575 in 2004. Although the fish wheel locations (and likely efficiencies) were different between some years, combined information suggests that fish wheel catch rates have been indicative of run magnitude.

EXPERIMENTAL ISSUES AND QUALIFICATIONS

Regardless of analytical procedures to compensate for tagging-induced mortality and precautions taken in handling fish, the abundance estimate has the potential to be biased from violation of the assumption that tagging does not influence catchability. Numerous studies of the mark-recapture technique have demonstrated substantial bias in abundance estimates from tagging studies because tagged and untagged individuals have not behaved similarly (Hilborn and Walters 1992). Furthermore, researchers have been cautioned when applying mark-recapture abundance estimates because of the uncertainty regarding the potential for increased mortality or differential movement of tagged and untagged fish (Ricker 1975; Schwarz and Taylor 1998). We attempted to remove this uncertainty by correcting for differential mortality with radio telemetry and associated analytical adjustments to the model. In addition, we made substantial efforts to minimize tagging-induced stress, to maximize the number of fish tagged and resampled within logistical constraints, and to verify that radio-tagged fish were capable of reaching disparate spawning destinations. These efforts removed a substantial amount of uncertainty regarding the behavior of tagged and untagged fish and therefore minimized bias.

The year-round inriver return is likely greater than estimated (as are escapement and marine survival) and harvest rates are likely lower than estimated because an unknown number of coho salmon adults enter the river before and after the mark-recapture experiment. Therefore, estimates presented here pertain only to the segment of the population targeted by the majority of existing fishing effort.

Factors influencing capture probability in all six abundance estimates (1999-2004) are unknown and untested. However, the efficiency of fish wheel and drift gillnetting gear are commonly thought to be influenced by water level, velocity, and transparency among other factors. The greatest range in water levels occurred in 2003, as did the lowest water level and the longest, consistent decrease in water level. The lowest fish wheel efficiency (catch/abundance at rkm 45) occurred in 2003 and was 2.5%. In 2004, the fish wheel efficiency was about 7.7% which was 83% greater than the next highest year (4.2%) during 2002, although water conditions were similar to most other years.

Significant changes to the tagging effort strategy and procedures that occurred between 1999 and 2003 likely contributed to a substantial increase in the proportion of tagged coho salmon that sustained upstream migration after tagging. Most of the fish that failed to sustain upstream migration were discovered to have died, presumably from capture and tagging-induced stress. In 1999, the weighted "mortality" rate was about 40% while it averaged 14% during (2000-2003). In 2004, the mortality rate increased slightly to 23%. Multiple factors to reduce handling time and stress to tagged fish evolved during previous studies and were employed in the 2004 study as detailed in Carlon and Evans (2007).

Pooling of data between tag types and banks in all years and in both events greatly simplified the analysis and improved precision. Estimates stratified by sub-categories were not required. Consistent handling and tagging procedures likely both contributed to the validity of pooling and are therefore considered beneficial in such an experiment. Consistency and care in handling and tagging should be a goal in this type of experiment to simplify analyses and improve precision.

In 2004, the daily fish wheel operational period was reduced during part of September compared to previous study years. Starting the second week of September, the fish wheel operational was reduced weekly at a rate roughly corresponding to the decrease in daylight. Changes to the 2004 fish wheel operational schedule resulted in complicating the CPUE comparisons amongst years. Analyzing fish wheel CPUE amongst years should be based upon similar year-to-year effort. Therefore, to conduct a comparative analysis of CPUE amongst years (1999-2004) data col1ected during 1999-2003 should be adjusted to utilize data collected only during fishing periods used in 2004.

Another factor that affected fish wheel effort stemmed from the record high catch of coho salmon (~9,600) in 2004. At times, fish wheel crewmembers were unable to keep up with tagging when coho salmon catches were very high. The non-target species catch (pink and sockeye salmon) also became an issued and high catch rates threatened to overcrowd the livebox(s) at times. In those instances, the crew would elect to shut-off one or more fish wheels long enough for them to "catch up". This was a relatively rare event, but combined with the reduction of fish wheel operational time enacted in September, the overall fishing effort in 2004 was lower than any previous study year.

Unquantified, but not uncommon anecdotal observations from multiple sources (the public and numerous field personnel) of dead fish in or downstream from the recapture reach indicates that mortality was likely not a rare event and that some gear-related, artificial mortality was imposed on coho salmon and other species. The negative impact on populations is unknown, but is considered minimal relative to each population. Using quantified information from coho salmon, the instantaneous mortality of coho salmon measured at the fish wheel (included in the "discounted" fish category) amounted to only several fish most years. In addition, the fish wheels in 2004 captured about 5% of the estimated total return. Post-release mortalities (as indicated by the weighted proportion of fish that failed to sustain upstream migration) of the marked sample (23%) represented less than 1.2% of the total return.

It is possible that drift net-caught fish were subject to a greater degree of mortality because of the mechanics of entanglement capture by gill nets. Regardless, mortality induced during recapture event sampling is also considered minimal because driftnets sampled such small portion of population (2.6%) of the estimated total coho salmon return. While incidental mortality is considered minimal, it is not considered unimportant because of its uncertain long-term biological impact and because of the potential for negative public perception. Public education regarding the actual extent of the impact to the coho salmon population should continue if the experiment is to be reestablished at some point in time. If variables causing high mortality from capture and handling in the lower intertidal stretch of the river could be greatly reduced (i.e. new capture or handling methods), the sport fishery could function as the recapture method; harvest sampling would be less costly than the current recapture strategy and would eliminate unnecessary mortality and public perception issues.

RECOMMENDATIONS

Indexing the inriver adult return using fish wheel CPUE.

In the absence of both an escapement goal and a project designed to estimate abundance, fish wheel catch rates may serve as a low-precision management tool to gauge abundance. Over the range of six years, the relationship between the $\log_e$-transformed cumulative catch rate and estimated abundance was linear (Figure 12) with a high degree of variation in point estimates of abundance accounted for in the regression. Although measurement error in CPUE observations was not accounted for, it is believed to be small compared to the historical variation in CPUE among years, and therefore of little consequence. A CPUE-based abundance index could serve to discern weak returns from strong. This method would be most effective near the latter end of the coho return and may be of questionable value earlier in the return.

Continue companion programs that estimate harvest components and smolt abundance

Since 1993, the annual UCI commercial harvest of Kenai River bound coho salmon has been estimated through a CWT recovery program. Sport and personal use harvest has been estimated for this population for decades and will continue to be estimated through the statewide harvest survey of sport anglers and through mandatory personal use permit reporting. To compliment this information, continuing to estimate the commercial harvest of this population in 2005 appears reasonable, especially given that a sufficient number of smolt have already been tagged for this purpose during the spring of 2004 and budget allocations exist for the commercial recovery effort. In the foreseeable future, continuation of the smolt abundance estimate should occur. If adult runs were to decline significantly again sometime in the future, smolt abundance estimates could serve to identify whether the decline is occurring during the freshwater or marine portion of their life cycle by filtering out variation in run abundance caused by variation in marine survival (Shaul et. al. 2003).

Continue support of genetic research.

Multiple resource agencies (Alaska Department of Fish and Game Sport Fish Division, United States Geologic Survey, and the United States Fish and Wildlife Service) have been involved in research designed to differentiate the genetic subdivisions comprising the Kenai River coho salmon population. The genetic structure of the population has not been completely studied, but baseline analyses of the Kenai River population (and others in Alaska) indicate that within-drainage genetic structure is discernable suggesting that management at a fine geographic scale may be justified to conserve genetic diversity (Olsen et al. 2003). Although it appears that the structure has a temporal component (structure changes over time), its nature is not yet clearly understood nor are the management implications. As emerging genetic information continues to take shape, fisheries management implications may need addressing.

To assist in expanding the knowledge base for Kenai River coho salmon population genetics, more research is needed and it is recommended that ADF&G continue to provide logistical and sampling support to the agencies conducting Kenai River coho salmon genetic research when possible.

Evaluate techniques to age coho salmon.

The accuracy of scale pattern analysis for aging coho salmon has recently been questioned, particularly for discerning freshwater age. Ageing error should be quantified or new techniques should be explored to ensure that brood class contributions to returns are accurate as possible.

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TABLES AND FIGURES

Table 1.–Possible fates and calculation of expected number by fate of adult coho salmon in the inriver return to the Kenai River as categorized for five annual mark-recapture experiments to estimate abundance, 2004.

Fate Code[a]	Description	Expected Value[b,c]	Model Parameter[d]
F01	Never captured.	$N - M - C + R$	
F02*	First captured in recapture reach.	$C - R$	*C*
F03	Marked with a spaghetti tag at the capture location, migrated upstream, was not harvested by the inriver sport fishery between the capture location and the recapture reach, and was not recaptured in recapture reach.	$M(1-q)p(1-H/N)[1-[C/(N-H)]]$	
F04*	Marked with a spaghetti tag at the capture location, migrated upstream, and was recaptured in the recapture reach.	$M(1-q)p(1-H/N)[C/(N-H)]$	*M, C, and R*
F05*	Marked with a spaghetti tag at the capture location, migrated upstream, and was harvested by the inriver sport fishery between the capture location and the recapture reach.	$M(1-q)p(H/N)$	*M*
F06*	Marked with a transmitter at the capture location, was not censored, migrated upstream, was not harvested by the inriver sport fishery between the capture location and the recapture reach, and was not recaptured in the recapture reach.	$Mq(1-\theta)p(1-H/N)[1-C/(N-H)]$	*M*
F07*	Marked with a transmitter at the capture location, was not censored, migrated upstream, and was recaptured in the recapture reach.	$Mq(1-\theta)p(1-H/N)[C/(N-H)]$	*M, C, and R*
F08*	Marked with a transmitter at the capture location, was not censored, migrated upstream, and was harvested by the inriver sport fishery between the capture location and the recapture reach.	$Mq(1-\theta)p(H/N)$	*M*
F09*	Marked with a transmitter at the capture location and censored.	$Mq\theta$	*M*
F10*	Marked with a transmitter at the capture location, was not censored, and did not sustain upstream migration.	$Mq(1-\theta)(1-p)$	*M*
F11	Marked with a spaghetti tag at the capture location and did not sustain upstream migration.	$M(1-q)(1-p)$	

[a] Fate codes marked with an asterisk (*) represent fates that were empirically assigned to fish through direct examination of capture, recapture, and telemetry data. The remaining fates were assigned to fish in the simulation procedure used to estimate the variance of abundance estimates.

[b] The intermediate terms q (the proportion of coho salmon captured in fish wheels and marked with a transmitter), θ (the proportion of radio-tagged coho salmon that were censored after release), and p (the proportion of radio-tagged fish that sustained upstream migration after release) in the equations used to generate expected values for all eleven fate categories were directly based on the number of fish empirically assigned to the "*-marked" fate categories.

[c] The term H represents the assumed harvest of all coho salmon occurring in the sport fishery between the capture location and the recapture reach.

[d] Model parameter to which each empirically determined fate category belongs; summing the number of fish in each empirically determined category and aggregating them within the associated model parameter provides the data required of the model (M, C, and R) for the point estimate of abundance. These data were temporally stratified if required by the chosen model.

Table 2.–Effort and tagging summary for coho salmon during the marking event, 2004.

Statistic	
Fish Wheel Effort (hours)	1,079.9
Total Catch	9,612
CPUE	8.901
Caught but Excluded from Marked Sample	
Escaped Prior to Tagging	46
Number Injured During Capture	5
Previously Captured by Driftnet	11
Radio-Tag Recaptures	3
Spaghetti-Tag Recaptures	306
Adipose Finclipped Fish Sacrificed	4
Total	375
Suitable for Tagging	
Tagged with Radio Tags	122
Tagged with Spaghetti Tags	9,115
Total	9,237

Table 3.–Effort and tagging summary for coho salmon during the marking event, 2004.

Statistic	
Drift Gillnet	
Effort (hrs)	254.0
Catch	5,160
CPUE	20.31
Set Gillnet	
Effort (hrs)	1.5
Catch	
Hook-and-Line	
Catch	12
Total Gear Combined	
Catch	5,172

Table 4.–Coho salmon encountering recapture effort sampling between riverkilometers 48.9 and 58.4, August 1 through October 5, 2004.

Statistic	
Coho Salmon Escaping Prior to Examination[a]	
Untagged	179
Radio-Tagged	
Spaghetti-Tagged	10
Total	189
Coho Salmon Captured Multiple Times[b]	
Untagged Fish Captured Twice	241
Untagged Fish Captured Three Times	10
Spaghetti-tagged Fish Captured Twice	17
Spaghetti-tagged Fish Captured Three Times	1
Untagged Fish with Unknown Prior Capture History	1
Total	270
Coho Salmon Captured and Examined[c]	
Untagged	4,380
Radio-Tagged	2
Spaghetti-Tagged	331
Total	4,713
Grand Total Encountering Gear[d]	5,172

[a] Coho salmon escaping prior to examination must also be subtracted from the Total Catch to determine the number examined for tags in the recapture event because these fish were not closely examined and therefore their release date (for recaptured tags) or prior capture status (number of dorsal punches) are unknown. Also, coho salmon that escaped during capture prior to close examination were not documented in 1999, but were in all other years; these categories are included here for tabulation consistency with all other years.

[b] Coho salmon captured multiple times must be subtracted from the Total Catch to determine the number examined in the recpature event because the study was designed to sample without replacement.

[c] The number of fish closely examined for tag status and prior examination status (number of dorsal punches). These fish constitute model parameter "C" (number of fish examined in the recapture event).

[d] Total number of coho salmon encountering recapture gear.

Table 5.–Two by two contingency table data and results of tests for independence between tag type and recapture rate in the amrk-recapture study to estimate the abundance of coho salmon in the Kenai River, 2004.

Tag Type	Number Released and Not Recaptured	Number Recaptured	Proportion Recaptured	χ^2	P-Value	Significance
Radio	120	2	0.016	0.86	0.353	NS
Spaghetti	8,784	331	0.036			

Table 6.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of radio-tagged (n1) and spaghett-tagged (n2) coho salmon captured in fish wheels in the Kenai River, 2004.

						Mean Length by Tag Type[a]	
Year	Radio Tagged Fish (n1)	Spaghetti-Tagged Fish (n2)	Test Statistic (Dmax)	P-Value	Significance	Radio	Spaghetti
2004	122	9,078	0.064	0.708	NS	649	649

[a] Lengths measured were fork lengths.

Table 7.–Two by two contingency table data and results of tests for independence between tag type and bank of recapture for coho salmon recaptured in the mark-recapture study to estimate abundance in the Kenai River, 2004.

	Number Recaptured		Proportion on			
Tag Type	North Bank	South Bank	North Bank	χ^2	P-Value	Significance
Radio	1	1	0.500	0.248	0.619	NS
Spaghetti	140	191	0.423			

Table 8.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of radio-tagged fish that sustained upstream migration after marking and those that did not in the mark-recapture study to estimate abundance of coho salmon in Kenai River, 2004.

	Sample Size				
Year	Sustained Upstream Migration	Did not Sustain Upstream Migration	Test Statistic (Dmax)	P-Value	Significance
2004	96	26	0.148	0.675	NS

Table 9.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of radio-tagged fish that sustained upstream migration and spaghetti-tagged fish that were recaptured in the mark-recapture study to estimate abundance of coho salmon from the Kenai River, 2004.

	Sample Size				
Year	Radio-Tagged Fish that Sustained Upstream Migration	Spaghetti-Tagged Fish that were Recaptured	Test Statistic (Dmax)	P-Value	Significance
2004	96	331	0.067	0.862	NS

Table 10.–Two by two contingency table data and results of tests for independence between bank of initial capture and the tendency for radio-tagged coho salmon to sustain upstream migration after marking in the mark-recapture experiment to estimate the abundance of coho salmon in the Kenai River, 2004.

Bank of Initial Capture	Number Not Sustaining Upstream Migration[a]	Number Sustaining Upstream Migration	Proportion Migrating Upstream	χ^2	P-Value	Significance
North	17	54	0.761	0.38	0.540	NS
South	9	42	0.824			

Table 11.–Contingency table data and results of tests for independence between recapture rate and bank of initial capture in the mark-recapture study to estimate the abundance of coho salmon in the Kenai River, 2004.

Bank of Initial Capture	Number Recaptured	Number Released And Not Recaptured	Proportion Recaptured	χ^2	P-Value	Significance
North	180	3920	0.044	12.68	P<.001	S
South	153	4984	0.030			

Note: Both tag types pooled.

Table 12.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of coho salmon captured in a fish wheel adjacent to the north bank of the Kenai River and those captured adjacent to the south bank in the mark-recapture study to estimate the abundance of coho salmon, 2004.

Year	North Bank Fish (n1)	South Bank Fish (n2)	Test Statistic (Dmax)	P-Value	Significance	Mean Length (mm) by Initial Bank of Capture[a] North	South
2004	4,078	5,122	0.033	0.015	S	651	648

[a] Lengths measured were FL.

Table 13.–Contingency table data and results of tests for independence between initial bank of capture and bank of recapture for Kenai River coho salmon, 2004.

Bank of Initial Capture	Bank of Recapture North	South	Proportion Recaptured Adjacent to Same Bank[b]	χ^2	P-Value	Significance
North	80	100	0.444	0.534	0.465	NS
South	61	92	0.601			

[a] Both tag types pooled.
[b] Proportion of the recapture sample for which bank of recapture was the same as bank of initial capture.

Table 14.–Contingency table data and results of tests for independence between bank of capture and the marked proportion of the catch of coho salmon in the recapture event of the mark-recapture study to estimate the abundance of coho salmon in the Kenai River, 2004.

Recapture Event Bank	Mark Status in Recapture Sample Marked	Unmarked	Proportion Marked	χ^2	P-Value	Significance
North	141	1,939	0.068	0.48	0.488	NS
South	192	2,422	0.073			

[a] Both tag types (radio and spaghetti) pooled.
[b] Data was culled from the first two days of effort and the last day to coincide with data used in abundance estimate.

Table 15.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of coho salmon captured along each bank of the recapture reach of the Kenai River in study to estimate the abundance of coho salmon, 2004.

Year	North Bank Fish (n1)	South Bank Fish (n2)	Test Statistic (Dmax)	P-Value	Significance	Mean Length (mm) by Recapture Reach Bank	
						North	South
2004	340	430	0.138	0.001	S	651	666

Table 16.–Performance of radio-tagged coho salmon by temporal interval, proportion sustaining upstream migration after marking by week, proportion of all marked coho salmon released by week, and weighted estimate of the proportion (p) of marked coho salmon sustaining upstream migration after marking in the Kenai River, Alaska, 2004.

Year	Interval	Number Spaghetti Tagged	Number Radio Tagged	Censored Radio Tags	Adjusted Tags Released	Number of Radio-tagged Fish Migrating Upstream	ϕ_i[a]	w_i[b]	$\hat{p} =$ $w_i\phi_i$[c]
2004	8/1-8/7	85	14		99	9	0[illegible]43	0.011	0.007
	8/8-8/14	716	14		730	10	0.714	0.079	0.056
	8/15-8/21	1,612	14		1,626	8	0.571	0.176	0.101
	8/22-8/28	1,786	14		1,800	8	0.571	0.195	0.111
	8/29-9/4	1,370	14		1,384	13	0.929	0.150	0.139
	9/5-9/11	1,115	14		1,129	12	0.857	0.122	0.105
	9/12-9/18	912	14		926	14	1.000	0.100	0.100
	9/19-9/25	983	14		997	13	0.929	0.108	0.100
	9/26-9/30	536	10		546	9	0.900	0.059	0.053
	Total	9115	122	0	9237	96		$\hat{p} =$	0.773

a Proportion of all uncensored radio tagged fish that sustained upstream migration after marking (by week).

b Proportion of all uncensored tagged fish released (by week).

c Proportion of all uncensored tags sustaining upstream migration (by week). The sum over all weekly periods in each year is the weighted estimate of the proportion (p) of all marked coho salmon sustaining upstream migration after marking.

Table 17.–Observations of marked and unmarked coho salmon captured in the recapture events of the mark-recapture experiment to estimate the abundance of coho salmon in the Kenai River, 2004, and results of tests for independence between mark status and temporal stratum.

Year	Temporal Recapture Stratum[b]	Number Examined	Number Unmarked	Number Marked	Proportion Marked	χ^2	P-Value	Significance
2004	8/1-8/14	213	206	7	0.033	50.775	<.001	S
	8/15-8/21	568	549	19	0.033			
	8/22-8/28	637	606	31	0.049			
	8/29-9/4	770	720	50	0.065			
	9/5-9/11	649	605	44	0.068			
	9/12-9/18	638	590	48	0.075			
	9/19-9/25	779	696	83	0.107			
	9/26-10/9	440	389	51	0.116			
	Total	4,694	4,361	333	0.071			

[a] Generally referred to in mark-recapture experiments as the "equal proportions test" of the hypothesis (and experimental assumption) that a) all fish in the population have an equal probability of capture and marking in the marking event or b) that probability of movement to recapture strata was independent of intital capture strata[a].

[b] Temporal strata were chosen (independently of strata chosen for final abundance estimates) to ensure that expected values in contingency table cells were >= 5 . In addition, days (and data) were culled from the beginning of the initial recapture stratum to synchronize the recapture data used in the equal proportions test with the culled data used to produce final estimates, i.e., examined fish that were excluded from the dataset used to produce final estimates were also excluded from the equal proportions tests.

Table 18.–Observations of number of coho salmon captured and marked by temporal marking stratum, number recaptured in the recapture event, and number not recaptured along with results of tests for independence between the recapture status and temporal marking stratum in mark-recapture study to estimate the abundance of coho salmon in the Kenai River, 2004.

Temporal Marking Stratum[b]	Number Marked	Adjusted Number Marked[c]	Number Not Recaptured	Number Recaptured	Proportion Recaptured	χ^2	P-Value	Significance
8/1-8/7	99	76.527	75.527	1	0.013	55.9337	<.001	
8/8-8/14	730	564.29	549.29	15	0.027			
8/15-8/21	1626	1256.898	1220.898	36	0.029			
8/22-8/28	1800	1391.4	1345.4	46	0.033			
8/29-9/4	1384	1069.832	1013.832	56	0.052			
9/5-9/11	1129	872.717	827.717	45	0.052			
9/12-9/18	926	715.798	678.798	37	0.052			
9/19-9/25	997	770.681	708.681	62	0.080			
9/26-10/2	546	422.058	387.058	35	0.083			
Total	9237	7140.201	6807.201	333	0.047			

[a] Generally referred to in mark-recapture experiments as the "mixing test" of the hypothesis (and experimental assumption) that a) all fish in the population have an equal probability of capture in the recapture event or b) that probability of movement to recapture strata was independent of intital capture strata, i.e., that marked fish mixed completely with unmarked fish between events.

[b] Temporal strata were chosen (independently of strata chosen for final abundance estimates) to ensure that expected values in contingency table cells were >= 5 .

[c] Adjusted to account for the proportion that did not sustain upstream migration (p statistic from Table 16).

Table 19.–Results of comparisons (Kolmogorov-Smirnov) between cumulative relative length distributions of coho salmon marked (M) and recaptured (R) and between coho salmon marked and those measured in the recapture event (C) in the mark-recaptured study to estimate the abundance of coho salmon in the Kenai River, 2004.

Year	Marked Fish[b] (M)	Recaptured Fish[c] (R)	Test Statistic (Dmax)	P-Value	Significance	Mean Length (mm) by Experimental Group: Marked (M)	Mean Length (mm) by Experimental Group: Recaptured (R)
2004	9,200	333	0.022	0.997	NS	649.2	650.7

Year	Marked Fish (M)	Recapture Event Fish[d] (C)	Test Statistic (Dmax)	P-Value	Significance	Mean Length (mm) by Experimental Group: Marked (M)	Mean Length (mm) by Experimental Group: Recapture Event (C)
2004	9,200	770	0.114	<0.001	S	649.2	659.5

[a] Days (and associated length data) were culled from the beginning and end of the recapture event length dataset to synchronize the recapture data used in length comparison tests with the culled data used to produce final estimates, i.e., measured fish that were excluded from the dataset used to produce final estimates were also excluded from category "C" in length comparisons.

[b] The definition of "marked fish" (M) in this table refers only to unique coho salmon captured by fishwheels when length was recorded prior to release and is not equal to the total number (9,237) of marked fish released including those without recorded lengths.

[c] Capture length (measured in the marking event) was substituted for lengths of recaptured fish

[d] Those fish that were captured in the recapture event, measured (capture lengths were substituted for recaptured fish) and not culled from the dataset used to generate abundance estimates.

Table 20.–Significance of statistical tests of primary assumptions for unbiased abundance estimates from a pooled Petersen estimator, conclusions about capture probabilities drawn from size independent and size-dependent (selectivity) tests, and abundance model selected in the mark-recapture study to estimate the abundance of coho salmon in the Kenai River, 2004.

	Size-Independent Capture Probability Tests			Size Selectivity KS Tests				
Year	Equal Propotions Test	Mixing Test	Differential P(Capture)[a]	M-R	M-C	R-C	Differential P(Capture)[a] by Size	Model Selected[b]
2004	S	S	In Both Events	NS	S	[c]	In Marking Event Only	ML Darroch

[a] P(Capture) means "probability of capture."

[b] Model selection following size-independent procedures of Arnason et al. (1996). Size selectivity tests suggested that stratification of estimates by size was unnecessary.

[c] Test unnecessary based on combination of other test results.

Table 21.–Mark release and recovery data and temporal stratification schemes used in the mark-recapture experiment to estimate the abundance of coho salmon in the Kenai River, 2004.

Mark Release Stratum	Total Number Marked	P[a]	Adjusted Number Marked[b]	Number of Marked Fish Recaptured by Recapture Stratum									
				8/3-8/7	8/8-8/14	8/15-8/21	8/22-8/28	8/29-9/4	9/5-9/11	9/12-9/18	9/19 - 9/25	9/26-10/3	Total
8/ 1 - 8/7	100	0.773	77	1	0	0	0	0	0	0	0	0	1
8/8-8/14	730	0.773	564	0	6	8	1	0	0	0	0	0	15
8/15-8/21	1,626	0.773	1,257	0	0	11	14	6	2	0	3	0	36
8/22-8/28	1,799	0.773	1,391	0	0	0	16	24	3	1	1	1	46
8/29-9/4	1,384	0.773	1,070	0	0	0	0	20	27	5	4	0	56
9/5-9/11	1,129	0.773	873	0	0	0	0	0	12	21	10	2	45
9/12-9/18	926	0.773	716	0	0	0	0	0	0	21	13	3	37
9/ 19 - 9/25	997	0.773	771	0	0	0	0	0	0	0	52	10	62
9/26 - 10/02	546	0.773	422	0	0	0	0	0	0	0	0	35	35
Total	9,237		7,141	1	6	19	31	50	44	48	83	51	333
Number Examined In Recapture Reach				26	187	568	637	770	649	638	779	440	4,694

Note: Days (and data) were culled from the beginning of each year's initial recapture stratum (when necessary) to account for the time required for marked fish to migrate into the recapture reach and become vulnerable to recapture gear. Likewise, days (and data) were culled from the end of the final recapture stratum to account for brief periods during which no marked fish were recovered and were not likely to be recovered because of presumed upstream migration and exit from the recapture reach.

[a] Estimated proportion of tagged fish surviving and sustaining upstream migration after marking (from Table 16).

[b] Adjusted Number Marked = p x Total Number Marked; accounts for marked fish that did not reestablish and sustain upstream migration after marking.

Table 22.–Estimated abundance of coho salmon in the Kenai River during selected time intervals, 1999 through 2004, with estimates of escapement.

			Total Abundance at Fish Wheels		Capture/Tagging Mortality		Discounted	Live Abundance		Upstream Sport Harvest[e,f]		Escapement	
Year[a]	Estimate Type	Estimate Interval[b]	Estimate	SE	Estimate[c]	SE	Fish Count[d]	Estimate	SE	Estimate	SE	Estimate	SE
1999	Pooled Petersen	8/ 6 - 9/30	23,001	5,154	175	18	18	22,808	5,157	15,112	1,171	7,696	5,288
2000	Pooled Petersen	8/ 1 - 10/ 6	89,918	9,295	515	93	40	89,363	9,322	16,621	1,165	72,742	9,395
2001	ML Darroch	8/ 2 - 9/30	93,524	16,502	528	88	12	92,984	16,502	17,862	1,540	75,122	16,574
2002	ML Darroch	8/ 2 - 9/30	156,960	20,256	942	235	26	155,992	20,255	22,380	1,442	133,612	20,306
2003	ML Darroch	8/ 4 - 9/30	99,309	36,085	190	74	19	99,100	36,085	19,185	1,372	79,915	36,111
2004	ML Darroch	8/1-9/30	120,489	9,008	2,097	372	9	118,383	9,000	22,989	2,692	95,394	9,394

[a] Estimates of abundance pertain to the riverkilometer 31 capture location in 1999 and riverkilometer 45 in 2000-2004.

[b] Estimates of abundance pertain to this temporal interval.

[c] Estimated number of all tagged fish that did not migrate upstream into the recapture reach based on fates of radio-tagged fish (=M(1-p^)).

[d] Atypically injured/stressed fish or adipose finclipped sacrificed fish (from Appendices A3, B3, C3, D3, and E3) ; these fish were excluded from model data.

[e] Source: Statewide harvest Survey. Sport harvest occurring upstream from the locations to which the abundance estimates pertain (in 1999, sum of SWHS estimates upstream of Soldotna Bridge including Skilak Lake, Hidden Lake, and Russian River; in 2000-2003, 1/2 of the SWHS estimate for the river section between the Soldotna Bridge and the Moose River confluence plus all estimated harvest upstream from the Moose River including Skilak Lake, Hidden Lake, and Russian River).

[f] Source: Statewide Harvest Survey. In 2002 and 2003, an "unspecified river reach" category was added to the SWHS for the Kenai River. Prior to calculating the sport harvest upstream from river kilometer 45, the estimates for this unspecified category were apportioned among the four specified mainstem river reaches based on the proportion of the total mainstem harvest represented by the reach-specific harvest reported (standard errors were recalculated according to standard procedures).

Table 23.–Estimates of total return, exploitation, and marine survival for coho salmon from the Kenai River, 1999 through 2004.

	Year					
Estimate	1999	2000	2001	2002	2003	2004
Abundance at Fish Wheels[a]	23,001	89,918	93,524	156,960	99,309	120,489
SE	5,154	9,295	16,502	20,256	36,085	9,008
Downstream Sport Harvest[b,c]	20,442	35,868	37,142	43,724	32,759	49,576
SE	1,454	1,740	1,878	2,516	1,908	10,577
Personal Use Harvest	1,009	1,449	1,555	1,721	1,332	2,661
SE	108	62	105	96	68	66
Commercial Harvest[d]	3,894	2,965	1,934	6,115	2,578	11,149
SE	326	255	176	499	263	1,232
Total Run	48,346	130,200	134,155	208,520	135,978	183,875
SE	5,366	9,460	16,610	20,418	36,137	13,948
Total Harvest[e]	40,457	56,903	58,493	73,940	55,854	86,375
SE	1,898	2,110	2,438	2,908	2,329	10,984
Exploitation Rate[f]	0.837	0.437	0.436	0.355	0.411	0.470
SE	0.101	0.036	0.057	0.037	0.110	0.020
Smolt Abundance in Prior Year[d]	799,687	578,355	601,236	641,693	626,335	1,196,310
SE	42,111	19,884	25,454	14,436	27,409	37,100
Marine Survival	0.060	0.225	0.223	0.325	0.217	0.150
SE	0.007	0.018	0.029	0.033	0.058	0.010

[a] Repeated from Table 22 for convenience.

[b] Source: Statewide Harvest Survey. Sport harvest occurring downstream from the locations to which the abundance estimates pertain (in 1999, sum of SWHS estimates downstream of Soldotna Bridge; in 2000-2004, 1/2 of the SWHS estimate for the river section between the Soldotna Bridge and the Moose River confluence plus all estimated sport harvest downstream from Soldotna Bridge).

[c] Source: Statewide Harvest Survey. In 2002 - 2004, an "unspecified river reach" category was added to the SWHS for the Kenai River. Prior to calculating the sport harvest downstream from river kilometer 45, the estimates for this category were apportioned among the four specified mainstem river reaches based on the proportion of the total mainstem harvest represented by the reach-specific harvest reported (standard errors were recalculated according to standard procedures).

[d] Sources: 1999-Massengill *In Prep*. a; 2000 and 2001-Massengill and Carlon 2004 a and b; 2002 and 2003-Massengill and Carlon *In Prep*. b and c; 2004-Massengill In Prep. b.

[e] Aggregate of all harvest estimates (sport, commercial, and personal-use/subsistence); repeated for convenience.

[f] (Estimated Grand Total Harvest) / (Estimated Total Return).

Table 24.–Natural Log-Transformed Fish Wheel CCPUE and related abundance estimates for Kenai River coho salmon, 1999-2004.

Year	ln(CCPUE)[a]	Estimated Abundance[b]
1999	3.63	23,001
2000	4.97	89,918
2001	4.47	93,524
2002	6.02	156,960
2003	4.65	99,309
2004	6.35	120,489
Average	5.02	

[a] This reflects the end-of-season ln(CCPUE) for the period of August 1 - September 30 during all years.

[b] Abundance estimate for coho salmon arriving to rkm 45.

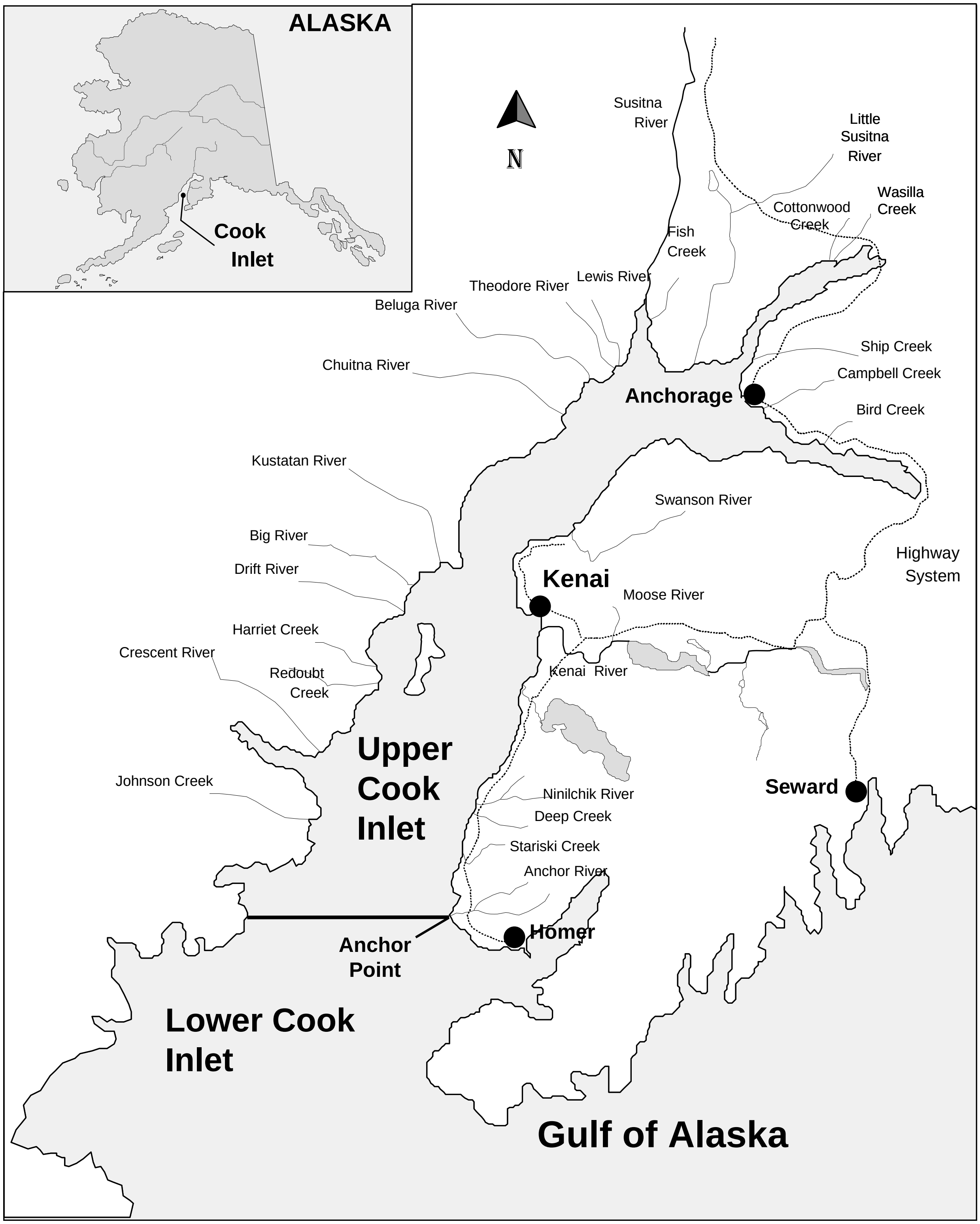

Figure 1.–Map of the Cook Inlet Basin with selected tributaries known to support coho salmon.

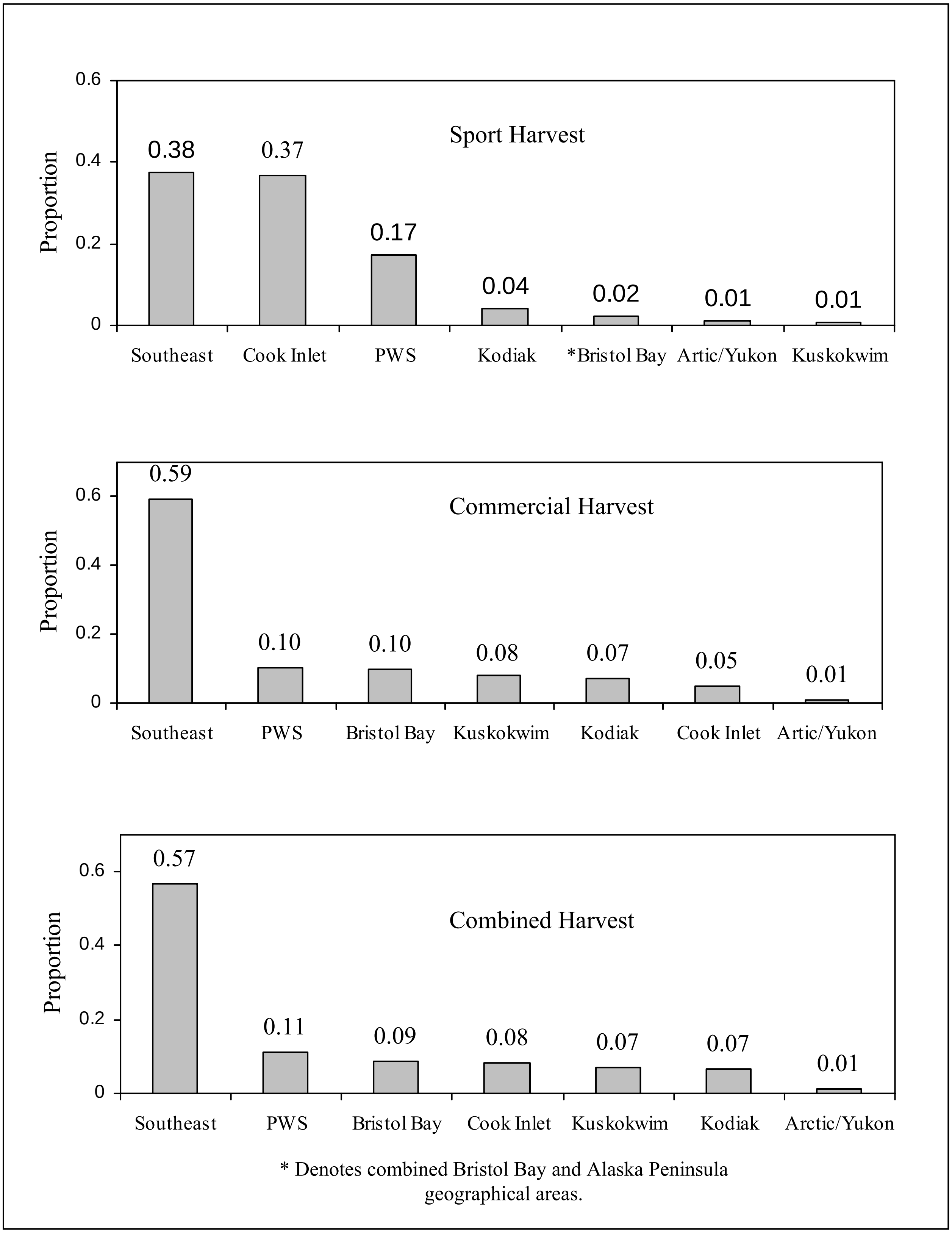

Figure 2.–Average proportions by region of the Statewide commercial and sport harvests of coho salmon, 1994 -2004.

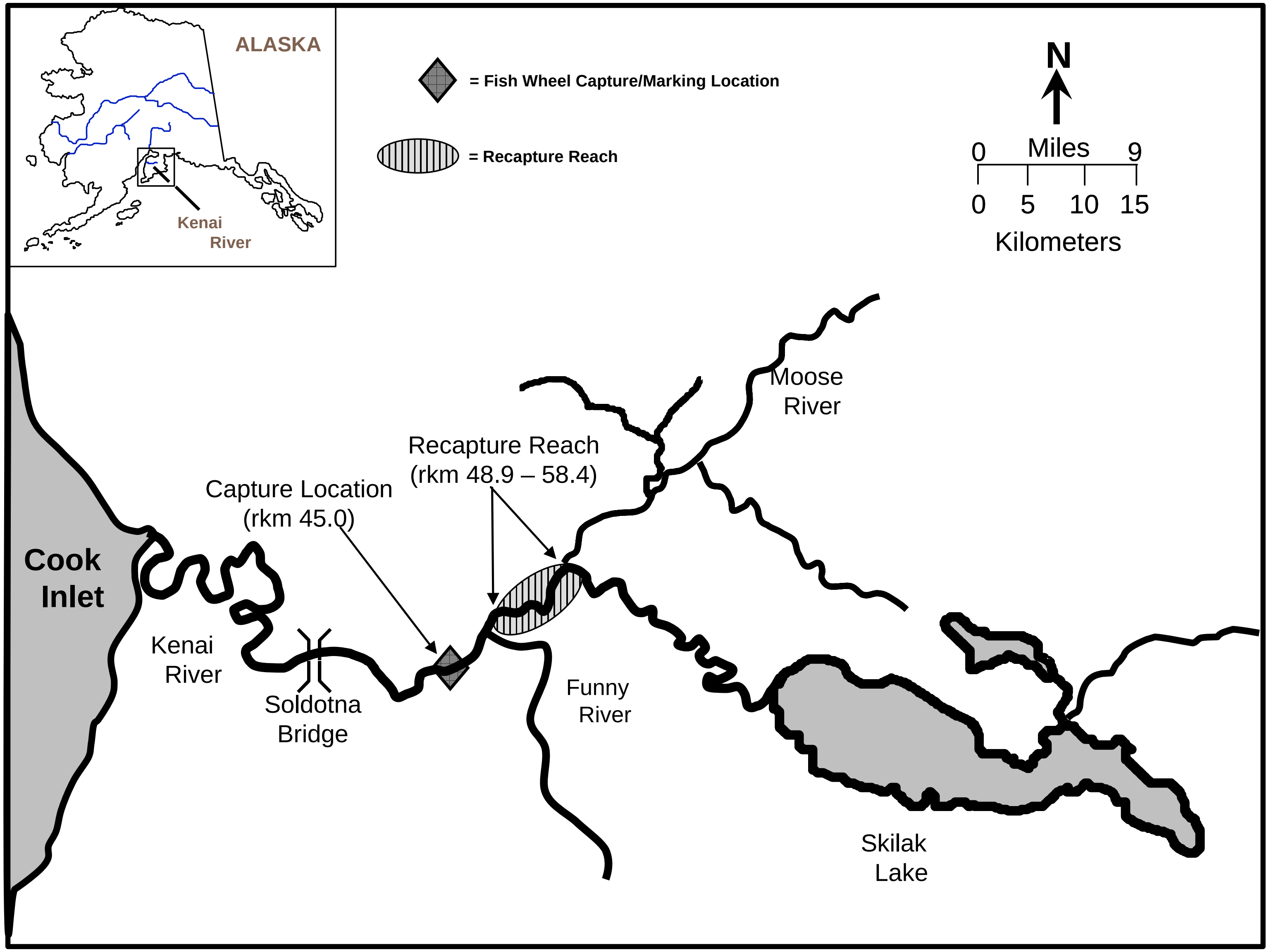

Figure 3. Map of the Kenai River with capture (marking) and recapture locations used in mark-recapture experiments to estimate the abundance of adult coho salmon, 2004.

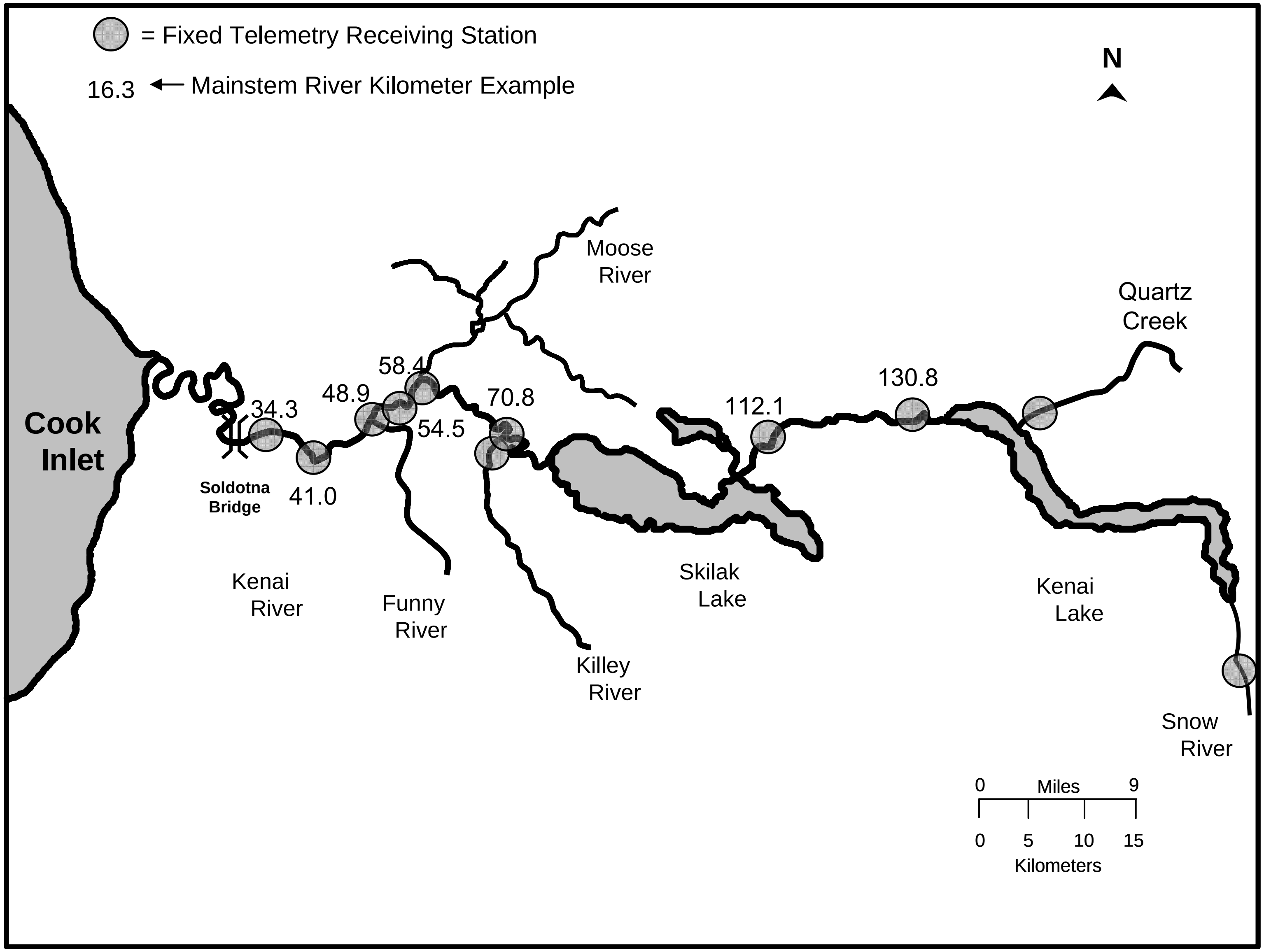

Figure 4. Map of the Kenai River and sites of the eleven fixed telemetry receiving stations installed to detect passage of radio-tagged coho salmon adults in the 2004 mark-recapture experiment to estimate adult abundance.

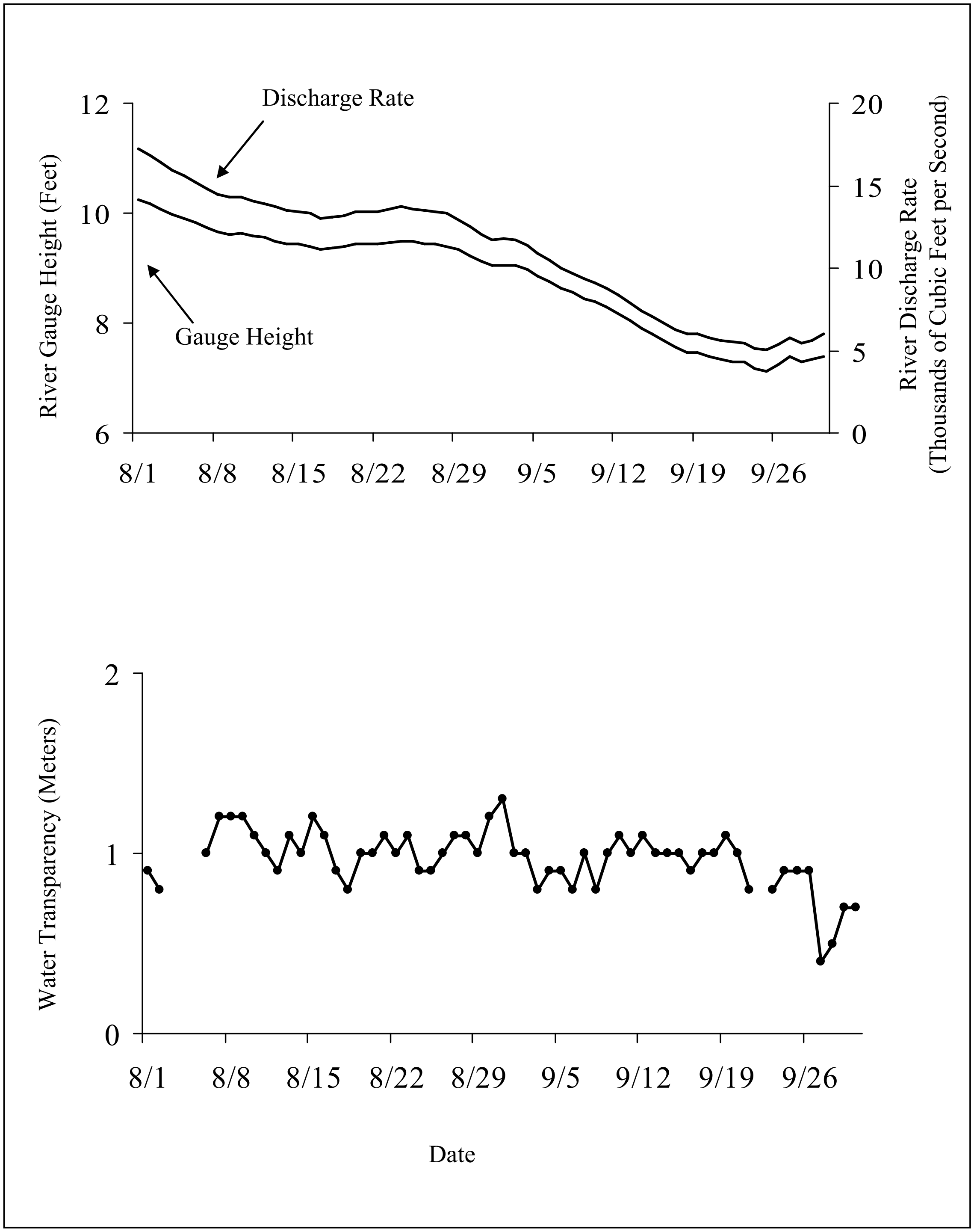

Figure 5.–Daily Kenai River stage and discharge volume as measured by a USGS gauging station at river kilometer (rkm) 34 (top) and water transparency as measured periodically with a Secchi disk near rkm 45 (bottom), August 1 through September 30, 2004.

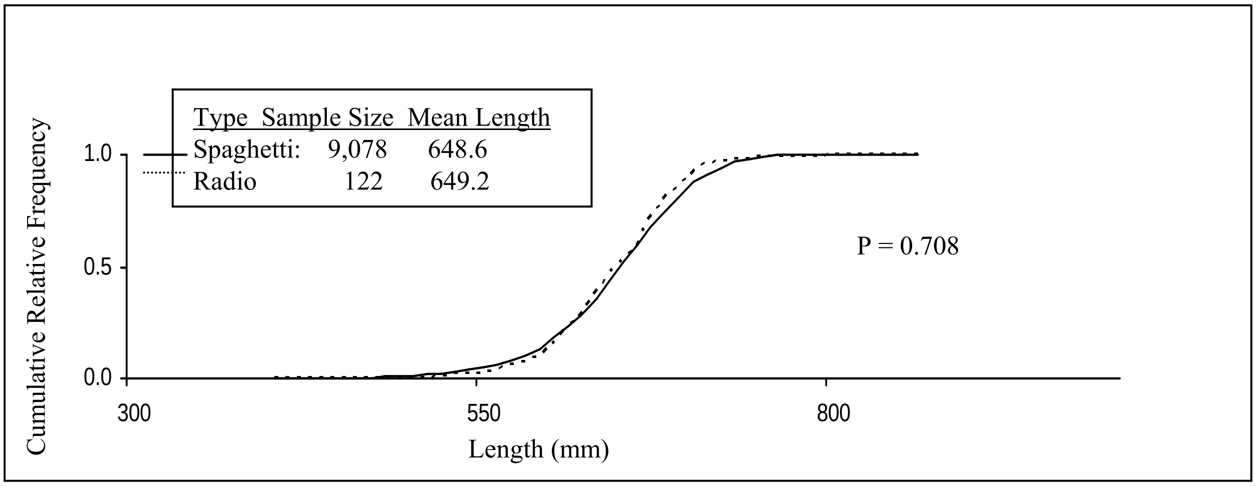

Figure 6.–Comparisons of cumulative relative length frequency distributions between coho salmon marked with radio tags and those marked with spaghetti tags in the marking event of the mark-recapture experiment to estimate the abundance of coho salmon in the Kenai River, 2004.

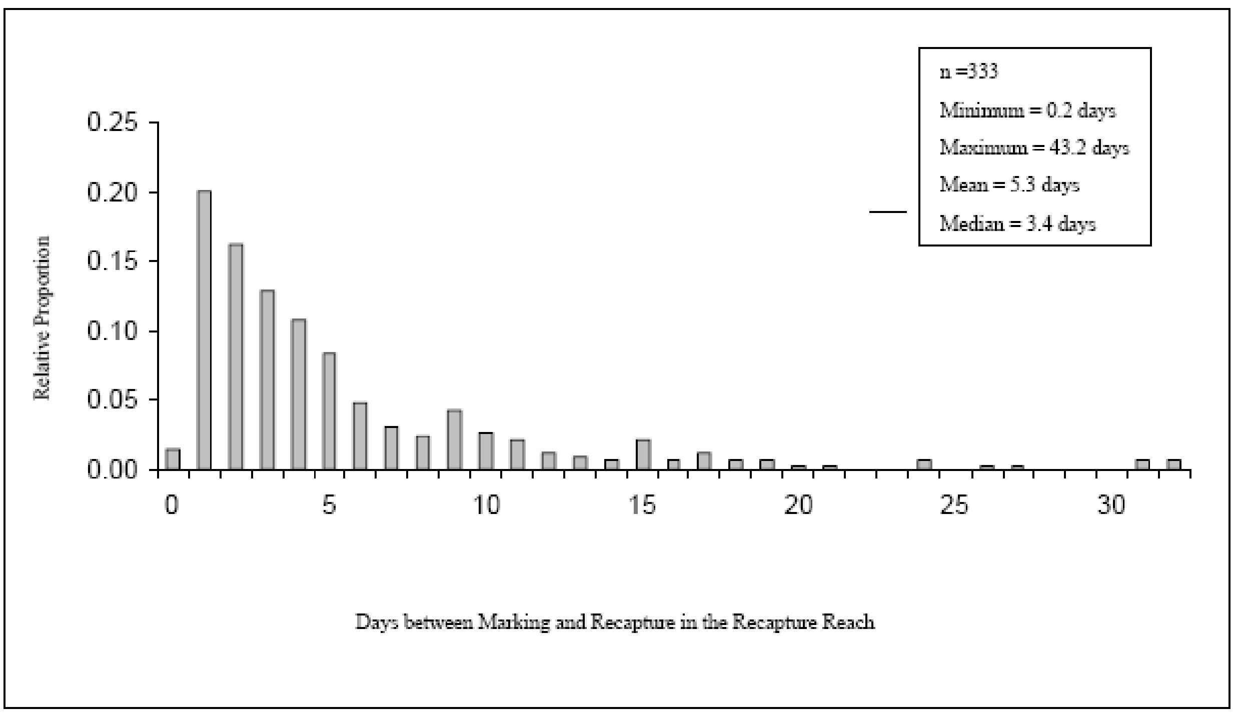

Figure 7.–Relative frequency distribution of 333 recaptured fish by days between marking and recapture for coho salmon marked with radio or spaghetti tags in the Kenai River mark-recapture experiment to estimate abundance, 2004.

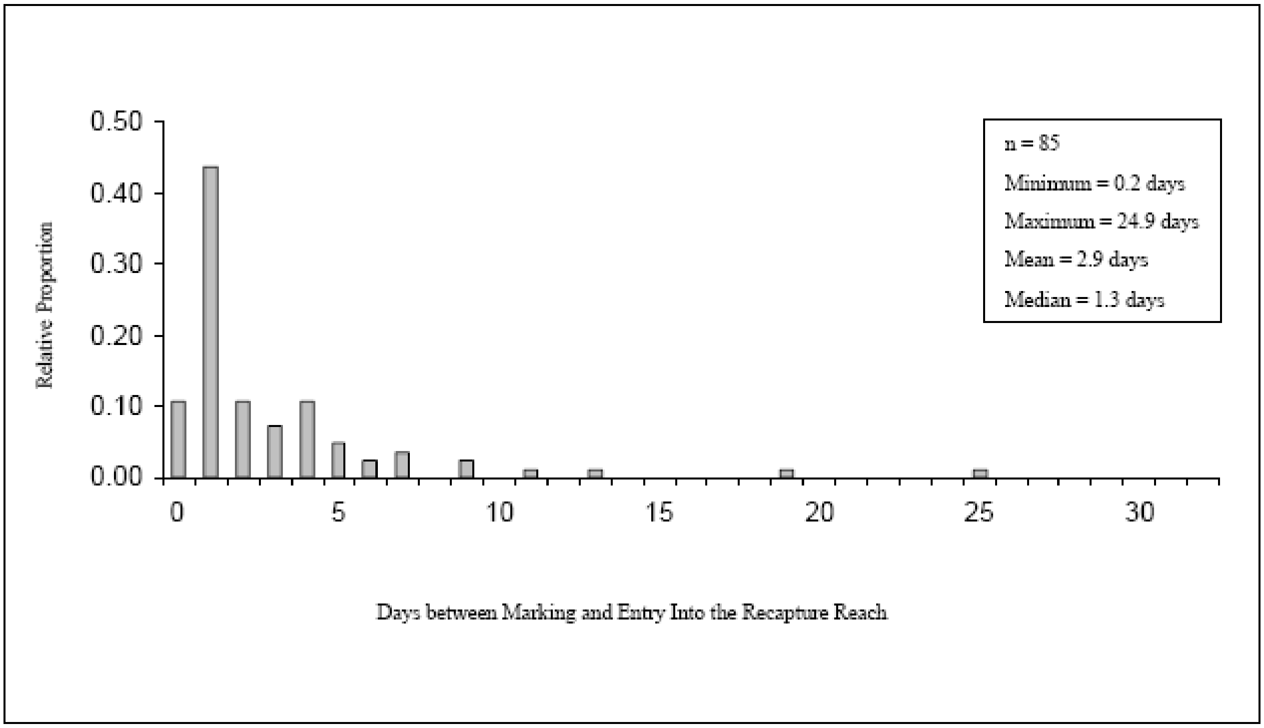

Figure 8.–Relative frequency distribution of 85 radio-tagged coho salmon by days between marking and entry into the recapture reach in the Kenai River mark-recapture experiment to estimate abundance, 2004.

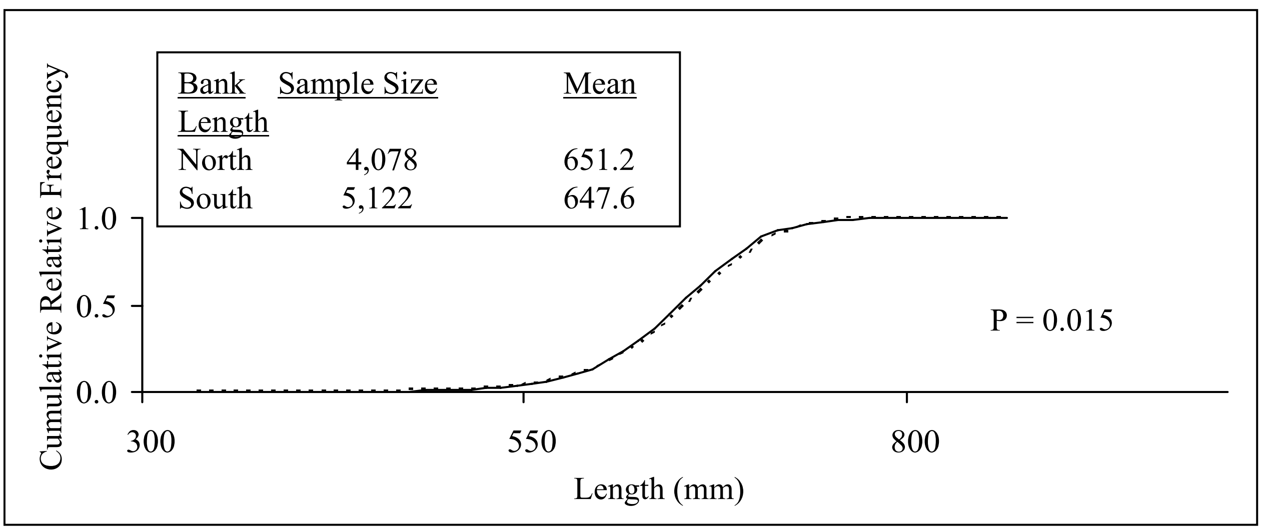

Figure 9.–Comparisons of cumulative relative length frequency distributions between coho salmon captured by fish wheels adjacent to the north and south banks of the Kenai River in the marking event of the mark-recapture experiment to estimate the abundance of coho salmon in the Kenai River, 2004.

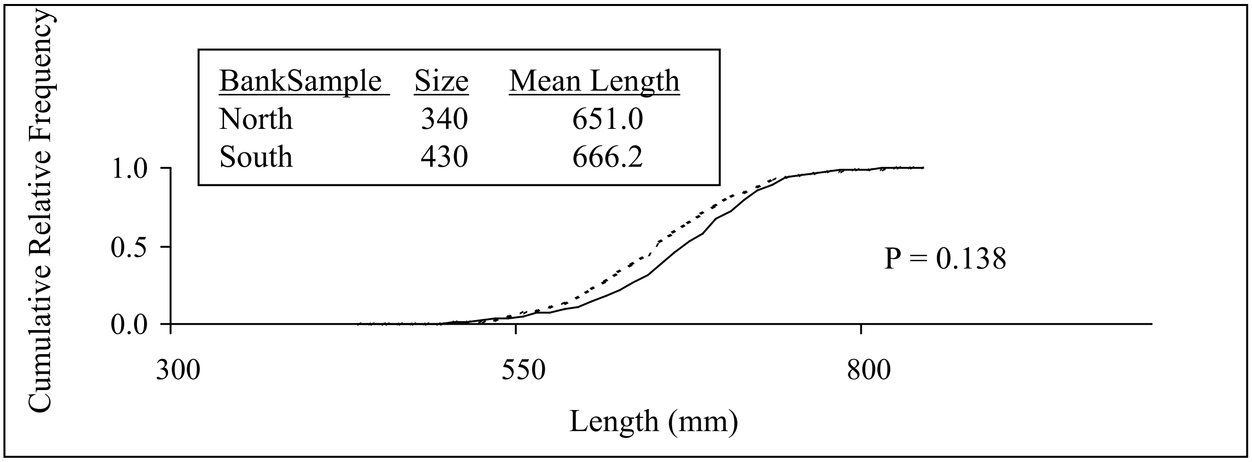

Figure 10.–Comparisons of cumulative relative length frequency distributions between coho salmon captured adjacent to the north and south banks of the Kenai River in the recapture event of the mark-recapture experiment to estimated coho salmon abundance, 2004.

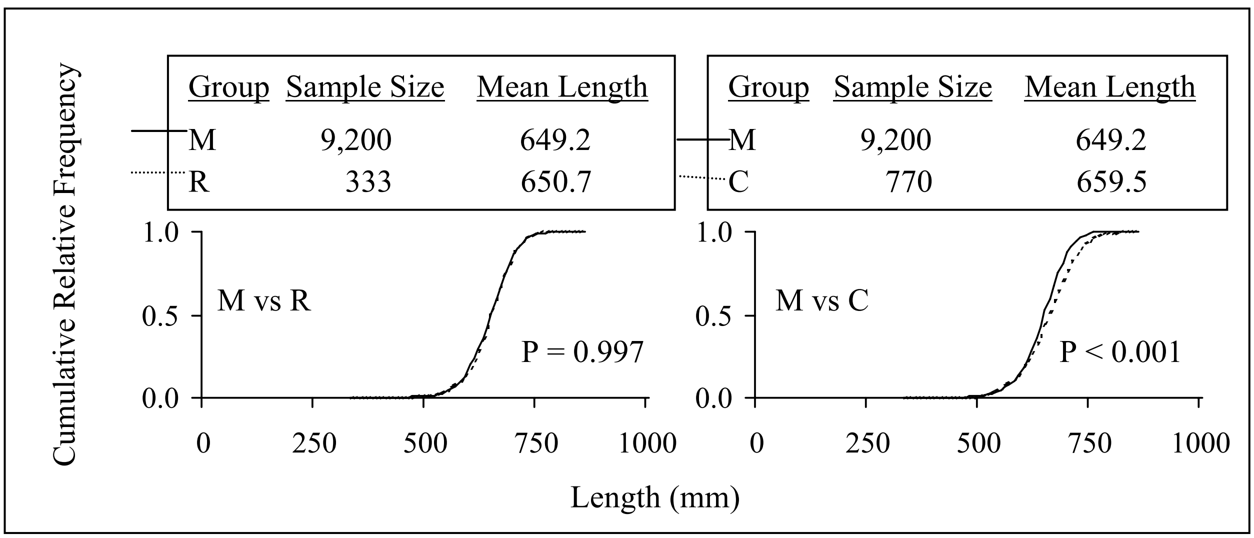

Figure 11.–Comparisons of cumulative relative length frequency distributions between coho salmon marked (M) and those recaptured (R) and between coho salmon marked and those captured, examined for marks, and measured (C) in the annual mark-recapture experiment to estimate abundance of coho salmon in the Kenai River, 2004.

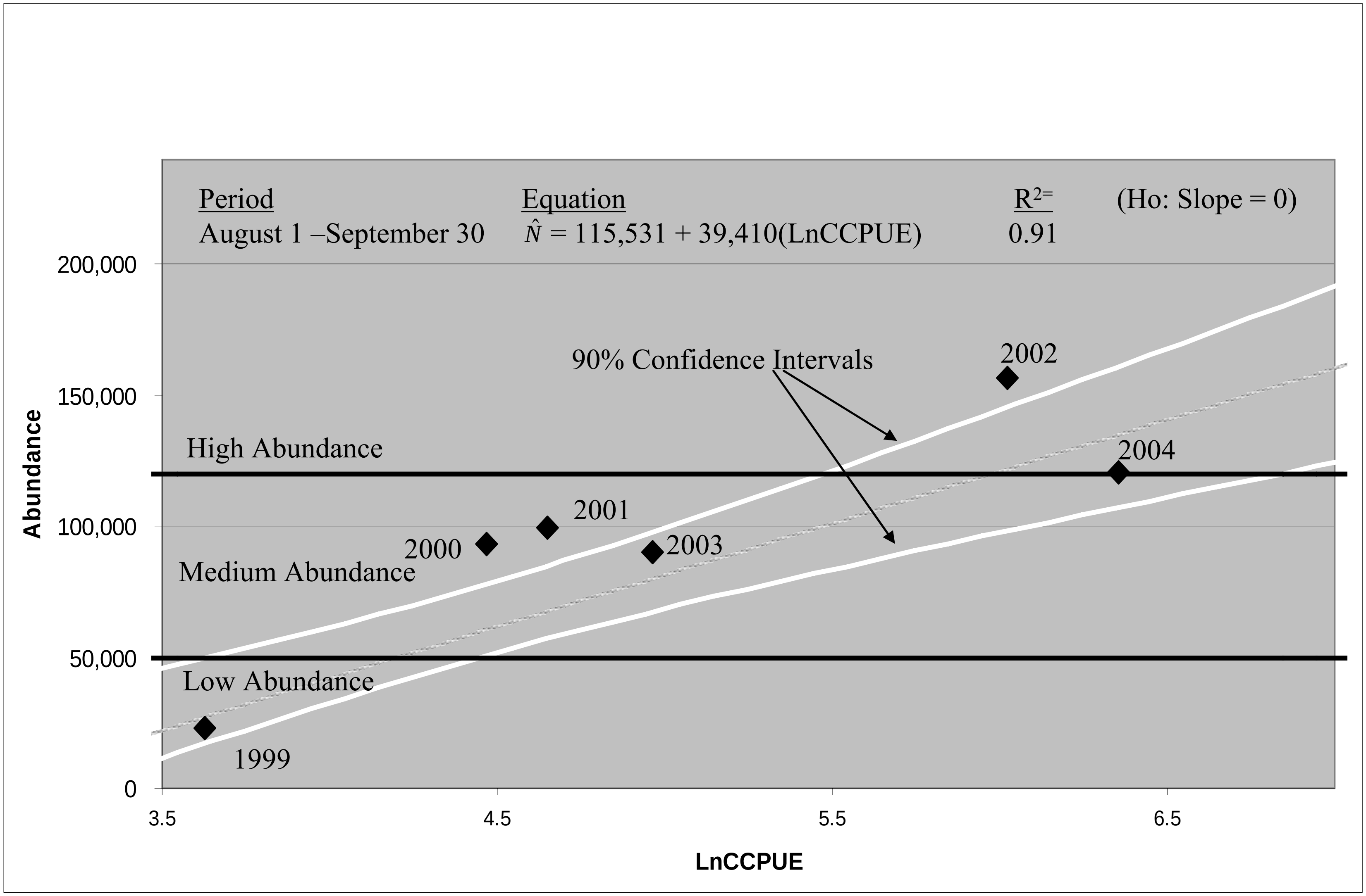

Figure 12.–Relationship between the natural logarithm transformation of year-end, cumulative daily coho salmon catch-per-hour by two fish wheels and mark-recapture point estimates of inriver coho salmon abundance, Kenai River, 1999 through 2004.

APPENDIX A

Appendix A1.–Standard Kolmogorov-Smirnov (K-S) test combinations and procedures for alleviating bias due to gear selectivity.

	Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	Fail to reject H°	Fail to reject H°
	Inference: There is no size-selectivity during either sampling event.	
Case II[d]	Fail to reject H°	Reject H°
	Inference: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III[e]	Reject H°	Fail to reject H°
	Inference: There is size-selectivity during both sampling events.	
Case IV[f]	Reject H°	Reject H°
	Inference: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S test compares lengths of fish marked during the first event (fish comprising model parameter "M") with lengths of fish recaptured during the second event (fish comprising model parameter "R"). H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test compares lengths of fish marked during the first event with lengths of fish captured during the second event (fish comprising model parameter "C"). H° for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events by length and estimate abundance for each length stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Apply a third K-S test comparing lengths of fish recaptured (fish comprising model parameter "R") with all fish captured and measured in the recapture event (fish comprising model parameter "C") to determine if there is length selectivity in the first event. H° for this third test is: The distribution of lengths of fish recaptured is the same as the distribution of lengths of fish sampled during the second event. Under a Case IV scenario, failure to reject the hypothesis of this third comparison implies no selectivity during the first event; calculate one unstratified abundance estimate and pool lengths and ages from the first sampling event for size and age composition estimates. Rejection of the hypothesis requires that a completely stratified abundance estimate be produced. For either outcome, estimate length and age compositions from the second event and adjust these estimates for differential capture probabilities.

AppendixA2.–List of data files collected for the mark-recapture experiement to estimate the abundance of coho salmon in the Kenai River, 2004.

Year	Type	File Name	File Description	DataMap File
2004	Raw Data	Capture2004.csv	All marking event data collected in 2004.	Capture2004_map.csv
	Raw Data	Recapture2004.csv	Recapture event data collected in 2004.	Recapture2004_map.csv
	Raw Data	FixedStation2004.csv	All radio telemetry data collected by automated stations in 2004.	FixedStation2004_map.csv
	Raw Data	RadioTracking2004.csv	All radio telemetry data collected by mobile tracking efforts in 2004.	RadioTracking2004_map.csv
	Raw Data	MiscRecovery2004.csv	All recoveries of fish marked in 2004 by methods other than the experimental recapture effort (angler returns, weirs, etc.)	MiscRecovery2004_map.csv
	Post-Processed	CTH2004.csv	Comprehensive tag histories ("CTH") for each mark released in 2004 (chronology of all records collected for each mark)	CTH2004_map.csv
	Post-Processed	FishHistory2004.csv	Necessary and sufficient subset of 2004 data for abundance estimation process.	FishHistory2004_map.csv

[a] All files are in ASCII comma delimited, dynamic field-width format (first row contains field names). All files are archived with an associated data map file. The data map files carry the same filename as the data files and a filename extension of ".dat." Data map files are in the same ASCII comma delimited format and contain a list of field descriptions (by field name and number) and descriptions of data values used in each field unless the values are self-explanatory.

[b] All files are archived in electronic format by the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services Section in Anchorage, Alaska.

AppendixA3.–Fish wheel catch by date, species, and riverbank near riverkilometer 45 of the Kenai River, Alaska, August 1 through September 30, 2004.

	Catch By Species																				
	North Bank										South Bank										Combined
Date	Coho	Sockeye	King	Pink	Chum	DV	RT	SH	WF	Total	Coho	Sockeye	King	Pink	Chum	DV	RT	SH	WF	Total	Bank Total
08/01		12								12	3	236		1			1			241	253
08/02	1	99	2	5						107	1	505	1	12		2	2			523	630
08/03	13	743	3	33		7	3			802	7	1,339		20		1				1,367	2,169
08/04	4	317		6		3				330	5	1,466	2	59		1				1,533	1,863
08/05	2	361	1	33						397	14	1,298	1	13		1				1,327	1,724
08/06	6	948		49						1,003	11	744	2	15			1			773	1,776
08/07	11	618	1	154						784	25	188	1	32		3				249	1,033
08/08	12	480		208						700	14	251		55						320	1,020
08/09	31	568		256			3			858	43	426		43		3				515	1,373
08/10	29	1,101		197						1,327	53	401		39		1				494	1,821
08/11	20	380		317			1			718	106	352		185		1				644	1,362
08/12	33	304		481		1	1			820	109	494		296		1				900	1,720
08/13	51	334	1	785		3				1,174	102	364		145		1	1			613	1,787
08/14	46	332		672						1,050	93	228		80						401	1,451
08/15	65	310		412						787	135	177	1	92						405	1,192
Subtotal	324	6,907	8	3,608	0	14	8	0	0	10,869	721	8,469	8	1,087	0	15	5	0	0	10,305	21,174
08/16	68	199		405						672	118	129	2	72		6	2			329	1,001
08/17	73	190	4	572		2	2			843	136	247	2	184		3	4	1		577	1,420
08/18	52	54		1,543			1			1,650	213	195	2	400		6	4		1	821	2,471
08/19	33	86		951		1	1			1,072	177	142	2	544			1			866	1,938
08/20	85	109		1,231						1,425	242	153	2	392			2	1		792	2,217
08/21	65	144		1,283			1			1,493	214	188	1	228		3	3			637	2,130
08/22	50	111		836		2	3			1,002	219	153		511		1	1			885	1,887
08/23	90	93	1	1,521		2	6			1,713	228	100		397			3			728	2,441
08/24	92	74	1	1,930						2,097	217	49	3	294		1	2			566	2,663
08/25	121	80		1,656			1			1,858	250	26		381		1	2			660	2,518
08/26	73	51		770			2			896	121	38		267		1				427	1,323
08/27	88	48		744			1			881	130	24		252		2	2			410	1,291
08/28	78	50		605		1	1			735	124	20		239						383	1,118
08/29	42	23		506			1			572	163	18	2	268		3	2			456	1,028
08/30	91	19	1	601		2	3			717	137	23		116		1				277	994
08/31	30	8		230		2	2			272	94	14	2	87		104	2			303	575
Subtotal	1,131	1,339	7	15,384	0	12	25	0	0	17,898	2,783	1,519	18	4,632	0	132	30	2	1	9,117	27,015

-continued-

Appendix A3.–Page 2 of 2.

	Catch By Species																				
	North Bank										South Bank										Combined
Date	Coho	Sockeye	King	Pink	Chum	DV	RT	SH	WF	Total	Coho	Sockeye	King	Pink	Chum	DV	RT	SH	WF	Total	Bank Total
09/01	69	35	1	434		1	5			545	171	17	2	311		2	1			504	1,049
09/02	67	25		490		3				585	183	6	1	362		1				553	1,138
09/03	73	6		511		3				593	121	3		222		2				348	941
09/04	78	15		396						489	146	6		231						383	872
09/05	46	24		241			2			313	125	16	2	179		4				326	639
09/06	70	10	1	296			1			378	142	16		127		4	2			291	669
09/07	82	20		397		2	2			503	60	5	1	58			1	1		126	629
09/08	55	13	1	158		1	1			229	62	2		40			2			106	335
09/09	104	12		243			1			360	52	1		13						66	426
09/10	113	23		418			1			555	97	3		11						111	666
09/11	118	10		252	1	1	4			386	51	1		9						61	447
09/12	91	7		97			1			196	142	1		14						157	353
09/13	87	7		142		2	4			243	92	2		25		1				120	363
09/14	75	5		59		2	1			142	39	2		5						46	188
09/15	98	3	1	48						150	25									25	175
Subtotal	1,226	215	4	4,182	1	15	23	0	0	5,667	1,508	81	6	1,607	0	14	6	1	0	3,223	8,890
09/16	80	2		32		3	5			122											122
09/17	112	2		41		1	4			160	6									6	166
09/18	97	1		19		1	4			122	17			2			3			22	144
09/19	93			2						95	16		1	1						18	113
09/20	169			18			8			195	50			2						52	247
09/21	90			4			6		1	101	22							1		23	124
09/22	135			6			4	1		146	46			8			2			56	202
09/23	148			10		1	2			161	49									49	210
09/24	93			14			5			112	18									18	130
09/25	85			11			3			99	20			1			1			22	121
09/26	95	1		17			9			122	16			2						18	140
09/27	82			2			4			88	84			10			11			105	193
09/28	69			6			7			82	9									9	91
09/29	82	1		5			4			92	6									6	98
09/30	118									118	12									12	130
Subtotal	1,548	7	0	187	0	6	65	1	1	1,815	371	0	1	26	0	0	17	1	0	416	2,231
Grand Total	4,229	8,468	19	23,361	1	47	121	1	1	36,249	5,383	10,069	33	7,352	0	161	58	4	1	23,061	59,310

Note: DV= Dolly Varden, RT = Rainbow Trout, SH = Steelhead, and WF = Whitefish.

[a] Catches include all fish captured daily including recaptured fish or those unsuitable for tagging.

AppendixA4.–Capture-recapture history of 333 tagged coho salmon recaptured between river kilometers 48.9 and 58.4 (recapture reach) of the Kenai River, Alaska, 2004.

Tag Type	Tag Number	Date and Time of Capture/ Tagging	Bank of Initial Capture/ Tagging	Date and Time of Recapture	Recapture Bank	Days Between Tagging and Recapture	Blank	Tag Type	Tag Number	Date and Time of Capture/ Tagging	Bank of Initial Capture/ Tagging	Date and Time of Recapture	Recapture Bank	Days Between Tagging and Recapture
Spaghetti	02429	8/6/04 13:07	S	8/7/04 16:18	S	1.13		Spaghetti	08526	9/7/04 18:21	N	9/24/04 16:22	N	16.92
Spaghetti	02577	8/9/04 17:17	S	8/11/04 15:07	S	1.91		Spaghetti	08539	9/7/04 20:23	N	9/22/04 9:39	S	14.55
Spaghetti	02595	8/10/04 7:29	S	8/14/04 12:53	S	4.23		Radio	00777	9/8/04 8:18	N	9/9/04 20:18	S	1.50
Spaghetti	02660	8/10/04 17:25	N	8/19/04 7:33	N	8.59		Spaghetti	08558	9/8/04 9:20	S	9/14/04 14:01	S	6.20
Spaghetti	02676	8/11/04 7:44	N	8/14/04 17:21	N	3.40		Spaghetti	08600	9/8/04 15:55	N	9/11/04 11:46	S	2.83
Spaghetti	02691	8/11/04 9:45	N	8/12/04 11:58	N	1.09		Spaghetti	08606	9/8/04 16:17	S	9/10/04 8:53	S	1.69
Spaghetti	02701	8/11/04 11:43	N	8/26/04 20:00	N	15.35		Spaghetti	08627	9/8/04 18:09	S	9/21/04 15:35	S	12.89
Spaghetti	02745	8/11/04 15:44	S	8/12/04 17:20	N	1.07		Spaghetti	08648	9/8/04 20:24	N	9/18/04 8:43	N	9.51
Spaghetti	02826	8/12/04 10:23	N	8/21/04 7:01	N	8.86		Spaghetti	08653	9/8/04 20:41	S	9/20/04 8:27	N	11.49
Spaghetti	02881	8/12/04 16:05	S	8/15/04 7:05	S	2.63		Spaghetti	08678	9/9/04 13:23	N	9/14/04 18:47	S	5.22
Spaghetti	02960	8/12/04 19:45	S	8/15/04 11:34	S	2.66		Spaghetti	08689	9/9/04 13:52	S	9/15/04 13:05	S	5.97
Spaghetti	02967	8/12/04 20:06	S	8/13/04 19:42	S	0.98		Spaghetti	08695	9/9/04 14:32	N	9/11/04 16:20	S	2.07
Spaghetti	03019	8/13/04 15:28	N	8/17/04 14:49	S	3.97		Spaghetti	08725	9/9/04 15:58	N	9/23/04 15:03	N	13.96
Spaghetti	03053	8/13/04 18:11	S	8/15/04 7:05	S	1.54		Spaghetti	08732	9/9/04 16:29	S	9/13/04 15:35	S	3.96
Spaghetti	03096	8/14/04 8:37	N	8/18/04 12:34	N	4.16		Spaghetti	08757	9/9/04 17:24	N	9/14/04 16:39	S	4.97
Spaghetti	03181	8/14/04 17:06	N	8/18/04 12:34	N	3.81		Spaghetti	08785	9/9/04 19:22	N	9/18/04 15:31	S	8.84
Spaghetti	03251	8/15/04 8:32	S	8/19/04 18:16	S	4.41		Spaghetti	08796	9/9/04 19:52	N	9/15/04 12:33	N	5.70
Spaghetti	03341	8/15/04 16:10	S	8/16/04 17:37	S	1.06		Spaghetti	08813	9/10/04 8:44	S	9/19/04 16:17	S	9.31
Spaghetti	03358	8/15/04 16:41	S	8/19/04 12:26	S	3.82		Spaghetti	08870	9/10/04 12:35	S	9/15/04 12:14	N	4.99
Spaghetti	03376	8/15/04 17:41	N	8/30/04 8:25	N	14.61		Spaghetti	08872	9/10/04 12:36	S	9/13/04 15:27	S	3.12
Spaghetti	03378	8/15/04 17:45	N	9/5/04 15:19	N	20.90		Spaghetti	08904	9/10/04 14:51	N	9/19/04 9:32	N	8.78
Spaghetti	03380	8/15/04 17:50	N	8/22/04 9:13	N	6.64		Spaghetti	08927	9/10/04 15:51	S	9/15/04 9:45	S	4.75
Spaghetti	03392	8/15/04 19:55	S	8/20/04 11:23	S	4.64		Spaghetti	08941	9/10/04 16:22	N	9/11/04 17:05	N	1.03
Spaghetti	03436	8/16/04 8:39	S	8/27/04 15:50	N	11.30		Spaghetti	08961	9/10/04 17:18	N	9/11/04 15:03	N	0.91
Spaghetti	03548	8/16/04 17:06	S	8/18/04 12:34	N	1.81		Spaghetti	08964	9/10/04 17:34	S	9/15/04 16:57	N	4.97
Spaghetti	03639	8/17/04 8:54	S	8/19/04 19:23	N	2.44		Spaghetti	08980	9/10/04 18:09	S	9/16/04 18:31	S	6.02
Spaghetti	03696	8/17/04 12:52	S	8/22/04 10:23	N	4.90		Spaghetti	09067	9/11/04 10:34	N	9/15/04 11:38	N	4.04
Spaghetti	03736	8/17/04 16:24	N	9/19/04 8:10	N	32.66		Spaghetti	09073	9/11/04 10:41	N	9/15/04 12:23	N	4.07
Spaghetti	03740	8/17/04 16:52	S	8/19/04 15:48	N	1.96		Spaghetti	09104	9/11/04 13:49	N	9/16/04 10:44	S	4.87
Spaghetti	03751	8/17/04 18:51	N	8/27/04 7:34	N	9.53		Spaghetti	09123	9/11/04 16:43	N	9/21/04 10:19	N	9.73
Spaghetti	03797	8/18/04 6:47	S	8/22/04 12:14	N	4.23		Spaghetti	09134	9/11/04 17:50	N	9/16/04 9:19	N	4.65
Spaghetti	03811	8/18/04 7:30	N	8/21/04 18:38	N	3.46		Spaghetti	09150	9/11/04 18:26	S	9/20/04 9:15	S	8.62
Spaghetti	03831	8/18/04 8:39	N	8/19/04 11:17	S	1.11		Spaghetti	09234	9/12/04 7:53	N	9/16/04 16:31	S	4.36
Spaghetti	03868	8/18/04 10:49	S	8/21/04 17:03	N	3.26		Spaghetti	09155	9/12/04 8:53	S	9/15/04 13:59	S	3.21
Spaghetti	03950	8/18/04 15:45	N	8/21/04 7:38	N	2.66		Spaghetti	09311	9/12/04 16:17	N	9/15/04 12:21	N	2.84
Spaghetti	04039	8/18/04 20:56	S	8/22/04 9:55	S	3.54		Spaghetti	09339	9/12/04 17:34	S	9/15/04 17:39	N	3.00
Spaghetti	04101	8/19/04 10:14	S	8/28/04 18:42	N	9.35		Spaghetti	09347	9/12/04 17:48	N	9/14/04 15:58	S	1.92
Spaghetti	04136	8/19/04 13:17	N	8/25/04 9:46	S	5.85		Spaghetti	09349	9/12/04 17:49	N	9/16/04 13:15	S	3.81
Spaghetti	04196	8/19/04 17:36	S	9/6/04 7:31	N	17.58		Spaghetti	09358	9/12/04 17:56	N	9/15/04 18:28	S	3.02
Spaghetti	04231	8/19/04 20:13	S	8/24/04 10:48	N	4.61		Spaghetti	09371	9/12/04 18:15	S	9/17/04 18:55	S	5.03
Spaghetti	04294	8/20/04 9:17	N	9/1/04 11:54	N	12.11		Spaghetti	09431	9/13/04 9:18	S	9/17/04 11:21	S	4.09
Spaghetti	04317	8/20/04 11:56	S	8/24/04 16:11	S	4.18		Spaghetti	09446	9/13/04 11:53	N	9/25/04 19:34	S	12.32
Spaghetti	04391	8/20/04 15:01	S	8/28/04 16:50	S	8.08		Spaghetti	09455	9/13/04 12:55	S	9/21/04 15:55	N	8.13
Spaghetti	04425	8/20/04 15:57	N	9/20/04 8:38	N	30.70		Spaghetti	09469	9/13/04 13:47	S	9/18/04 14:53	S	5.05
Spaghetti	04441	8/20/04 16:23	S	8/31/04 19:55	N	11.15		Spaghetti	09473	9/13/04 13:57	N	9/17/04 16:32	S	4.11
Spaghetti	04484	8/20/04 17:48	N	9/20/04 8:38	N	30.62		Spaghetti	09502	9/13/04 14:19	N	9/19/04 9:51	S	5.81
Spaghetti	04487	8/20/04 17:54	N	8/28/04 15:37	S	7.90		Spaghetti	09486	9/13/04 16:01	S	9/16/04 16:39	S	3.03
Spaghetti	04515	8/20/04 19:23	N	8/22/04 9:55	S	1.61		Spaghetti	09565	9/13/04 20:08	N	9/16/04 10:04	N	2.58
Spaghetti	04517	8/20/04 19:32	S	9/3/04 15:31	N	13.83		Radio	00789	9/14/04 9:26	N	9/30/04 9:54	N	16.02
Spaghetti	04577	8/20/04 21:04	S	8/25/04 7:18	N	4.43		Spaghetti	09589	9/14/04 10:46	S	9/15/04 12:21	N	1.07
Spaghetti	04616	8/21/04 8:02	S	9/2/04 20:19	N	12.51		Spaghetti	09598	9/14/04 12:45	N	10/4/04 8:50	S	19.84
Spaghetti	04654	8/21/04 10:24	S	8/30/04 20:19	S	9.41		Spaghetti	09648	9/14/04 17:11	N	9/15/04 10:40	S	0.73
Spaghetti	04906	8/22/04 9:11	N	8/30/04 15:15	N	8.25		Spaghetti	09668	9/14/04 20:06	S	9/18/04 9:47	S	3.57
Spaghetti	04911	8/22/04 9:37	S	9/1/04 15:34	N	10.25		Spaghetti	09685	9/15/04 8:25	N	9/16/04 9:50	S	1.06
Spaghetti	04976	8/22/04 13:04	S	8/24/04 15:34	N	2.10		Spaghetti	09716	9/15/04 10:26	N	9/16/04 18:45	S	1.35
Spaghetti	04977	8/22/04 13:05	S	10/4/04 16:59	N	43.16		Spaghetti	09728	9/15/04 12:43	N	9/21/04 15:10	S	6.10
Spaghetti	05019	8/22/04 16:01	S	8/26/04 8:13	N	3.68		Spaghetti	09806	9/16/04 9:32	N	9/22/04 16:42	S	6.30
Spaghetti	05053	8/22/04 17:27	N	9/3/04 8:24	N	11.62		Spaghetti	09840	9/16/04 16:51	N	9/17/04 15:34	S	0.95
Spaghetti	05068	8/22/04 18:07	S	8/24/04 7:27	S	1.56		Spaghetti	09860	9/16/04 17:51	N	9/18/04 12:00	S	1.76
Spaghetti	05151	8/23/04 8:42	N	8/31/04 15:30	S	8.28		Spaghetti	09885	9/17/04 11:15	N	9/18/04 17:13	S	1.25
Spaghetti	05167	8/23/04 9:16	S	8/26/04 9:33	N	3.01		Spaghetti	09908	9/17/04 14:13	N	9/19/04 10:11	S	1.83
Spaghetti	05203	8/23/04 11:57	S	8/28/04 17:27	S	5.23		Spaghetti	09937	9/17/04 17:14	N	9/19/04 9:14	S	1.67
Spaghetti	05255	8/23/04 15:54	S	9/1/04 19:53	S	9.17		Spaghetti	09939	9/17/04 17:16	N	9/20/04 13:14	S	2.83
Spaghetti	05277	8/23/04 16:32	S	9/11/04 16:47	N	19.01		Spaghetti	09951	9/17/04 18:27	N	9/19/04 8:50	S	1.60
Spaghetti	05432	8/23/04 17:09	N	8/29/04 13:03	N	5.83		Spaghetti	09966	9/17/04 19:51	N	9/20/04 16:00	N	2.84
Spaghetti	05449	8/23/04 19:51	N	9/16/04 19:50	S	24.00		Spaghetti	09967	9/17/04 19:53	N	10/4/04 12:57	N	16.71
Spaghetti	05360	8/23/04 19:54	S	8/24/04 17:17	S	0.89		Spaghetti	10014	9/18/04 14:10	N	9/23/04 19:35	N	5.23
Spaghetti	05363	8/23/04 20:02	S	8/25/04 16:30	S	1.85		Spaghetti	10036	9/18/04 14:32	N	9/21/04 12:54	S	2.93
Spaghetti	05366	8/23/04 20:09	S	9/2/04 12:34	N	9.68		Spaghetti	10048	9/18/04 16:05	N	9/21/04 17:41	N	3.07
Spaghetti	05508	8/24/04 11:49	S	8/28/04 17:11	S	4.22		Spaghetti	10130	9/19/04 14:05	N	9/22/04 12:20	S	2.93
Spaghetti	05715	8/24/04 17:42	S	9/4/04 8:59	S	10.64		Spaghetti	10170	9/19/04 16:51	N	9/22/04 15:29	S	2.94

AppendixA5.–Number of fish encountered by gear, date, bank, and species in the Kenai River, Alaska, between rkm 48.9 and 58.4 (recapture reach), August 1 through October 5, 2004.

		Catch By Species																					
		North Bank										South Bank											Combined
Gear [b]	Date	Coho	Sockeye	King	Pink	DV	RT	SH	LNS	Unk	Total	Coho	Sockeye	King	Pink	DV	RT	SH	WF	AC	Unk	Total	Bank Total
Drift Net	08/01		19	8	1	1	2				31		21	4			1					26	57
Drift Net	08/02		59	10	1	2	4				76	2	56	13		2	5					78	154
Drift Net	08/03		92	9	4	1	3				109	2	63	8	2	2	3					80	189
Drift Net	08/04	1	82	11		2	2				98		80	10		2	4					96	194
Drift Net	08/05		155	13	2	1	4				175	3	135	17		2	4					161	336
Drift Net	08/06	4	154	13	5	1	10				187	5	115	7	6	2	3					138	325
Drift Net	08/07	9	135	9	7		6				166	6	120	20	9	4	11					170	336
Drift Net	08/08	7	55	11	10	2					85	3	48	10	2	1						64	149
Drift Net	08/09	2	39	14	14	3	2				74	4	39	17	9		4					73	147
Drift Net	08/10	11	94	4	17	1	1				128	7	60	10	18		1					96	224
Drift Net	08/11	4	142	14	31	1	3				195	15	134	12	22	2	7					192	387
Drift Net	08/12	26	141	15	97	1	3			1	284	18	149	21	64	1	11					264	548
Drift Net	08/13	32	86	7	57		5				187	11	80	16	36	2	7					152	339
Drift Net	08/14	26	127	5	104		3				265	28	91	10	50	2	1					182	447
Drift Net	08/15	23	80	1	98		1				203	24	72	4	54		5					159	362
Subtotal		145	1,460	144	448	16	49	0	0	1	2,263	128	1,263	179	272	22	67	0	0	0	0	1,931	4,194
Drift Net	08/16	29	56	5	82	1	1			1	175	21	56	11	50	1	2					141	316
Drift Net	08/17	36	74	11	119		4				244	28	83	11	120	2	6					250	494
Drift Net	08/18	49	62	2	149		3				265	58	61	6	188		1				1	315	580
Drift Net	08/19	51	57	8	179	2	6				303	58	78	15	238	1						390	693
Drift Net	08/20	54	40	4	149		2				249	42	67	9	225	1	3					347	596
Drift Net	08/21	46	64	8	212		2				332	65	86	9	256		1					417	749
Drift Net	08/22	21	23	3	147						194	29	26	4	194	2	2					257	451
Drift Net	08/23	27	30	1	122		1				181	26	23	6	131	1						187	368
Drift Net	08/24	53	37	5	263	1	1				360	42	22	7	267		1					339	699
Drift Net	08/25	45	31	9	178		2				265	47	26	4	213		2					292	557
Drift Net	08/26	70	33	11	284		2				400	57	28	12	343	1	4					445	845
Drift Net	08/27	57	9	6	191		1				264	47	30	3	250		2					332	596
Drift Net	08/28	65	12	4	222	2	3				308	77	16	5	226	1						325	633
Drift Net	08/29	27	2	1	113		1				144	35	5		160		2					202	346
Drift Net	08/30	26	5	3	129	1					164	35	7	2	156							200	364
Drift Net	08/31	76	5	6	177		1				265	53	6	3	232	1						295	560
Subtotal		732	540	87	2,716	7	30	0	0	1	4,113	720	620	107	3,249	11	26	0	0	0	1	4,734	8,847

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		Catch by Species																					
		North Bank										South Bank											Combined
Gear [b]	Date	Coho	Sockeye	King	Pink	DV	RT	SH	LNS	Unk	Total	Coho	Sockeye	King	Pink	DV	RT	SH	WF	AC	Unk	Total	Bank Total
Drift Net	09/01	55	6	6	273		4				344	53	12	4	267	1	2					339	683
Drift Net	09/02	135	6	5	320	1	2				469	58	5	3	420	1	1					488	957
Drift Net	09/03	76	7	3	215	1	1				303	63	4	1	305							373	676
Drift Net	09/04	85	4	2	317	2	3				413	44	3	3	235	1						286	699
Drift Net	09/05	29	1	1	140	1	1				173	18	2	3	149							172	345
Drift Net	09/06	44	6	1	136	1	3				191	22	2	1	102		1					128	319
Drift Net	09/07	59	1	4	215	2	3				284	45	7	3	247	3	1					306	590
Drift Net	09/08	75	1		214	2	1				293	52	11		141		4					208	501
Drift Net	09/09	57	4	1	244	1					307	64	2	2	282		4					354	661
Drift Net	09/10	53	2	4	199		2				260	61	3	1	175	1	5		1			247	507
Drift Net	09/11	53	4	1	119		3				180	83	4	1	172		6					266	446
Drift Net	09/12	33	1	1	49		1				85	25			46		1					72	157
Drift Net	09/13	33	1	1	95	1	6				137	33			63	2	2					100	237
Drift Net	09/14	22	3	3	139	3	4				174	64	2		125	8	3					202	376
Drift Net	09/15	51		2	122	4	9				188	64			156	12	8					240	428
Subtotal		860	47	35	2,797	19	43	0	0	0	3,801	749	57	22	2,885	29	38	0	1	0	0	3,781	7,582
Drift Net	09/16	30		2	104	1	3				140	114	2		97	4	12					229	369
Drift Net	09/17	40			82	1	3				126	91	1		61	4	13					170	296
Drift Net	09/18	42	3	1	68	2	4				120	82		1	102	3	14					202	322
Drift Net	09/19	57	1		37		2		1		98	44	1		28	2	7	1				83	181
Drift Net	09/20	58			21	1	1				81	51	2		30	1	9					93	174
Drift Net	09/21	74	2	1	44	1	9				131	128	3		42	5	16					194	325
Drift Net	09/22	28	1		18	1	7				55	101	3		50	5	15	2				176	231
Drift Net	09/23	29			51	1	10				91	110			74	4	18	1				207	298
Drift Net	09/24	29			32		9				70	100	2		19	1	8			1		131	201
Drift Net	09/25	11			7	1	2				21	64			18		13	1				96	117
Drift Net	09/26	10			17		3	2			32	28			21	1	14					64	96
Drift Net	09/27	7			20		5				32	49			23	1	16	1				90	122
Drift Net	09/28	14			34		15				63	54	1		22	1	37					115	178
Drift Net	09/29	15			15		8				38	58	1		13		45					117	155
Drift Net	09/30	45	1		4	1	17				68	54	1		6	4	42	2				109	177
Subtotal		489	8	4	554	10	98	2	1	0	1,166	1,128	17	1	606	36	279	8	0	1	0	2,076	3,242

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		Catch by Species																					
		North Bank										South Bank											Combined
Gear [b]	Date	Coho	Sockeye	King	Pink	DV	RT	SH	LNS	Unk	Total	Coho	Sockeye	King	Pink	DV	RT	SH	WF	AC	Unk	Total	Bank Total
Drift Net	10/01	14	1		11		12				38	40			7	2	20					69	107
Drift Net	10/02	9	1		3	3	3				19	62	3		7		35					107	126
Drift Net	10/03	5			5		6				16	20			4		22					46	62
Drift Net	10/04	16			2	1	10	1			30	24					30					54	84
Drift Net	10/05	8					1				9	11	1		5	1	15					33	42
Subtotal		52	2	0	21	4	32	1	0	0	112	157	4	0	23	3	122	0	0	0	0	309	421
Drift Net Total		2,278	2,057	270	6,536	56	252	3	1	2	11,455	2,882	1,961	309	7,035	101	532	8	1	1	1	12,831	24,286
Hook-Line	08/28														5							5	5
Subtotal		0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5	5
Hook-Line	09/05											1			1							2	2
Hook-Line	09/06														1							1	1
Subtotal		0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	3	3
Hook-Line	09/16														1							1	1
Hook-Line	09/24	5									5	2			1	1						4	9
Hook-Line	09/25	4									4												4
Subtotal		9	0	0	0	0	0	0	0	0	9	2	0	0	2	1	0	0	0	0	0	5	14
Hook-Line	10/01					1					1												1
Subtotal		0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Hook-Line Total		9	0	0	0	1	0	0	0	0	10	3	0	0	9	1	0	0	0	0	0	13	23
Gear Combined	08/01		19	8	1	1	2				31		21	4			1					26	57
Gear Combined	08/02		59	10	1	2	4				76	2	56	13		2	5					78	154
Gear Combined	08/03		92	9	4	1	3				109	2	63	8	2	2	3					80	189
Gear Combined	08/04	1	82	11		2	2				98		80	10		2	4					96	194
Gear Combined	08/05		155	13	2	1	4				175	3	135	17		2	4					161	336
Gear Combined	08/06	4	154	13	5	1	10				187	5	115	7	6	2	3					138	325
Gear Combined	08/07	9	135	9	7		6				166	6	120	20	9	4	11					170	336
Gear Combined	08/08	7	55	11	10	2					85	3	48	10	2	1						64	149
Gear Combined	08/09	2	39	14	14	3	2				74	4	39	17	9		4					73	147
Gear Combined	08/10	11	94	4	17	1	1				128	7	60	10	18		1					96	224
Gear Combined	08/11	4	142	14	31	1	3				195	15	134	12	22	2	7					192	387
Gear Combined	08/12	26	141	15	97	1	3			1	284	18	149	21	64	1	11					264	548
Gear Combined	08/13	32	86	7	57		5				187	11	80	16	36	2	7					152	339
Gear Combined	08/14	26	127	5	104		3				265	28	91	10	50	2	1					182	447
Gear Combined	08/15	23	80	1	98		1				203	24	72	4	54		5					159	362
Subtotal		145	1,460	144	448	16	49	0	0	1	2,263	128	1,263	179	272	22	67	0	0	0	0	1,931	4,194
Gear Combined	08/16	29	56	5	82	1	1			1	175	21	56	11	50	1	2					141	316
Gear Combined	08/17	36	74	11	119		4				244	28	83	11	120	2	6					250	494
Gear Combined	08/18	49	62	2	149		3				265	58	61	6	188		1				1	315	580
Gear Combined	08/19	51	57	8	179	2	6				303	58	78	15	238	1						390	693
Gear Combined	08/20	54	40	4	149		2				249	42	67	9	225	1	3					347	596
Gear Combined	08/21	46	64	8	212		2				332	65	86	9	256		1					417	749

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		Catch by Species																					
		North Bank										South Bank											Combined
Gear [b]	Date	Coho	Sockeye	King	Pink	DV	RT	SH	LNS	Unk	Total	Coho	Sockeye	King	Pink	DV	RT	SH	WF	AC	Unk	Total	Bank Total
Gear Combined	08/22	21	23	3	147						194	29	26	4	194	2	2					257	451
Gear Combined	08/23	27	30	1	122		1				181	26	23	6	131	1						187	368
Gear Combined	08/24	53	37	5	263	1	1				360	42	22	7	267		1					339	699
Gear Combined	08/25	45	31	9	178		2				265	47	26	4	213		2					292	557
Gear Combined	08/26	70	33	11	284		2				400	57	28	12	343	1	4					445	845
Gear Combined	08/27	57	9	6	191		1				264	47	30	3	250		2					332	596
Gear Combined	08/28	65	12	4	222	2	3				308	77	16	5	231	1						330	638
Gear Combined	08/29	27	2	1	113		1				144	35	5		160		2					202	346
Gear Combined	08/30	26	5	3	129	1					164	35	7	2	156							200	364
Gear Combined	08/31	76	5	6	177		1				265	53	6	3	232	1						295	560
Subtotal		732	540	87	2,716	7	30	0	0	1	4,113	720	620	107	3,254	11	26	0	0	0	1	4,739	8,852
Gear Combined	09/01	55	6	6	273		4				344	53	12	4	267	1	2					339	683
Gear Combined	09/02	135	6	5	320	1	2				469	58	5	3	420	1	1					488	957
Gear Combined	09/03	76	7	3	215	1	1				303	63	4	1	305							373	676
Gear Combined	09/04	85	4	2	317	2	3				413	44	3	3	235	1						286	699
Gear Combined	09/05	29	1	1	140	1	1				173	19	2	3	150							174	347
Gear Combined	09/06	44	6	1	141	1	3				196	22	2	1	103		1					129	325
Gear Combined	09/07	59	1	4	215	2	3				284	45	7	3	247	3	1					306	590
Gear Combined	09/08	75	1		214	2	1				293	52	11		141		4					208	501
Gear Combined	09/09	57	4	1	244	1					307	64	2	2	282		4					354	661
Gear Combined	09/10	53	2	4	199		2				260	61	3	1	175	1	5		1			247	507
Gear Combined	09/11	53	4	1	119		3				180	83	4	1	172		6					266	446
Gear Combined	09/12	33	1	1	49		1				85	25			46		1					72	157
Gear Combined	09/13	33	1	1	95	1	6				137	33			63	2	2					100	237
Gear Combined	09/14	22	3	3	139	3	4				174	64	2		125	8	3					202	376
Gear Combined	09/15	51		2	122	4	9				188	64			156	12	8					240	428
Subtotal		860	47	35	2,802	19	43	0	0	0	3,806	750	57	22	2,887	29	38	0	1	0	0	3,784	7,590
Gear Combined	09/16	30		2	104	1	3				140	114	2		98	4	12					230	370
Gear Combined	09/17	40			82	1	3				126	91	1		61	4	13					170	296
Gear Combined	09/18	42	3	1	68	2	4				120	82		1	102	3	14					202	322
Gear Combined	09/19	57	1		37		2		1		98	44	1		28	2	7	1				83	181
Gear Combined	09/20	58			21	1	1				81	51	2		30	1	9					93	174
Gear Combined	09/21	74	2	1	44	1	9				131	128	3		42	5	16					194	325
Gear Combined	09/22	28	1		18	1	7				55	101	3		50	5	15	2				176	231
Gear Combined	09/23	29			51	1	10				91	110			74	4	18	1				207	298
Gear Combined	09/24	34			32		9				75	102	2		20	2	8			1		135	210
Gear Combined	09/25	15			7	1	2				25	64			18		13	1				96	121
Gear Combined	09/26	10			17		3	2			32	28			21	1	14					64	96
Gear Combined	09/27	7			20		5				32	49			23	1	16	1				90	122
Gear Combined	09/28	14			34		15				63	54	1		22	1	37					115	178
Gear Combined	09/29	15			15		8				38	58	1		13		45					117	155
Gear Combined	09/30	45	1		4	1	17				68	54	1		6	4	42	2				109	177
Subtotal		498	8	4	554	10	98	2	1	0	1,175	1,130	17	1	608	37	279	8	0	1	0	2,081	3,256

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Appendix A5.–Page 5 of 5.

		Catch by Species																					
		North Bank										South Bank											Combined
Gear [b]	Date	Coho	Sockeye	King	Pink	DV	RT	SH	LNS	Unk	Total	Coho	Sockeye	King	Pink	DV	RT	SH	WF	AC	Unk	Total	Bank Total
Gear Combined	10/01	14	1		11	1	13				40	40			7	2	20					69	109
Gear Combined	10/02	9	1		3	3	3				19	62	3		7		35					107	126
Gear Combined	10/03	5			5		6				16	20			4		22					46	62
Gear Combined	10/04	16			2	1	10	1			30	24					30					54	84
Gear Combined	10/05	8					1				9	11	1		5	1	15					33	42
Subtotal		52	2	0	21	5	33	1	0	0	114	157	4	0	23	3	122	0	0	0	0	309	423
Gear Combined Total		2,287	2,057	270	6,541	57	253	3	1	2	11,471	2,885	1,961	309	7,044	102	532	8	1	1	1	12,844	24,315

Note: DV= Dolly Varden, RT = Rainbow Trout, SH = Steelhead, LNS = Longnose sucker, Unk = Unknown species.

[a] Includes fish that encountered the recapture gear but escaped before close examination and fish captured multiple times (in addition to those captured and examined).

[b] Incidntal use of set gill netting technique was tried but proved unproductive and was discontinued, only a few pinks were captured and that catch data was omitted from this table.

AppendixA6.–Capture history and fates assigned to 122 coho salmon captured from the Kenai River near river kilometer 45 and marked with radio transmitters, August 1 through September 30, 2004.

Order of Capture	Fate Code	Experimental Fate[a]	Tag Number	Capture Date	Capture Time	Capture Bank	Fork Length (mm)	Days to Enter Recapture Reach[b]
1	F06	Upstreamer	00700	08/01	13:19	S	620	9.2
2	F06	Upstreamer	00701	08/01	18:10	S	670	
3	F06	Upstreamer	00702	08/02	12:31	S	640	24.9
4	F10	Downstreamer	00703	08/02	19:40	N	675	
5	F10	Downstreamer	00704	08/03	10:38	S	670	
6	F10	Downstreamer	00705	08/03	15:15	N	600	
7	F06	Upstreamer	00706	08/04	7:59	S	630	0.9
8	F10	Downstreamer	00707	08/05	11:28	S	650	
9	F06	Upstreamer	00708	08/05	12:58	S	640	0.2
10	F06	Upstreamer	00709	08/05	14:59	S	670	0.9
11	F06	Upstreamer	00710	08/06	7:42	S	640	0.2
12	F06	Upstreamer	00711	08/06	18:46	N	670	2.4
13	F10	Downstreamer	00712	08/07	8:21	S	700	
14	F06	Upstreamer	00713	08/07	15:25	S	620	1.2
15	F06	Upstreamer	00714	08/08	8:02	N	620	1.1
16	F06	Upstreamer	00715	08/08	16:14	N	650	0.8
17	F06	Upstreamer	00716	08/09	7:00	S	690	0.7
18	F10	Downstreamer	00717	08/09	14:43	N	600	
19	F10	Downstreamer	00718	08/10	7:01	N	670	
20	F06	Upstreamer	00719	08/10	20:37	S	610	1.9
21	F06	Upstreamer	00720	08/11	7:40	N	640	7.1
22	F06	Upstreamer	00733	08/11	19:27	N	670	
23	F18	Downstreamer	00732	08/12	7:15	N	650	
24	F10	Downstreamer	00731	08/12	20:23	S	570	
25	F06	Upstreamer	00721	08/13	12:35	S	710	2.1
26	F06	Upstreamer	00722	08/13	16:29	N	700	3.8
27	F06	Upstreamer	00723	08/14	8:55	S	710	
28	F06	Upstreamer	00724	08/14	20:46	S	580	5.0
29	F06	Upstreamer	00725	08/15	13:05	S	670	
30	F06	Upstreamer	00726	08/15	15:58	S	620	4.8
31	F10	Downstreamer	00727	08/16	8:07	N	630	
32	F10	Downstreamer	00728	08/16	16:06	N	660	
33	F06	Upstreamer	00729	08/17	12:42	S	610	2.0
34	F10	Downstreamer	00730	08/17	16:34	N	650	
35	F10	Downstreamer	00734	08/18	12:36	S	710	
36	F10	Downstreamer	00735	08/18	19:21	S	630	
37	F06	Upstreamer	00736	08/19	12:58	S	640	1.3
38	F10	Downstreamer	00737	08/19	17:17	N	660	
39	F06	Upstreamer	00738	08/20	8:12	N	690	
40	F06	Upstreamer	00739	08/20	19:26	N	580	13.3
41	F06	Upstreamer	00740	08/21	13:09	S	630	
42	F06	Upstreamer	00741	08/21	17:15	N	680	
43	F10	Downstreamer	00742	08/22	11:02	N	610	
44	F06	Upstreamer	00743	08/22	15:39	S	660	
45	F06	Upstreamer	00744	08/23	9:35	S	600	
46	F06	Upstreamer	00745	08/23	20:30	S	680	
47	F06	Upstreamer	00746	08/24	8:11	S	690	19.4
48	F10	Downstreamer	00747	08/24	20:16	N	630	
49	F06	Upstreamer	00748	08/25	7:05	N	650	2.7
50	F10	Downstreamer	00751	08/25	20:24	N	610	
51	F10	Downstreamer	00749	08/26	9:11	N	680	
52	F06	Upstreamer	00752	08/26	18:25	N	560	0.8
53	F10	Downstreamer	00753	08/27	13:40	N	590	
54	F10	Downstreamer	00754	08/27	15:10	N	730	
55	F06	Upstreamer	00755	08/28	11:32	N	680	5.6
56	F06	Upstreamer	00756	08/28	15:30	S	620	3.9
57	F06	Upstreamer	00757	08/29	12:05	S	660	2.6
58	F06	Upstreamer	00758	08/29	21:20	S	630	3.8
59	F10	Downstreamer	00759	08/30	7:19	S	670	
60	F06	Upstreamer	00760	08/30	20:02	N	600	4.9
61	F06	Upstreamer	00761	08/31	7:41	S	610	0.5
62	F06	Upstreamer	00762	08/31	18:14	S	740	
63	F06	Upstreamer	00763	09/01	8:38	S	620	
64	F06	Upstreamer	00764	09/01	20:42	S	660	
65	F06	Upstreamer	00765	09/02	12:35	S	670	
66	F06	Upstreamer	00766	09/02	15:43	S	610	
67	F06	Upstreamer	00767	09/03	10:39	N	720	
68	F06	Upstreamer	00768	09/03	18:03	N	610	
69	F06	Upstreamer	00769	09/04	12:38	N	640	
70	F06	Upstreamer	00770	09/04	21:13	S	690	
71	F06	Upstreamer	00771	09/05	12:01	S	700	
72	F06	Upstreamer	00772	09/05	14:53	N	600	
73	F06	Upstreamer	00773	09/06	7:22	S	800	
74	F06	Upstreamer	00774	09/06	17:30	S	610	
75	F10	Downstreamer	00775	09/07	11:48	S	660	
76	F06	Upstreamer	00776	09/07	20:33	N	640	
77	F07	Upstreamer	00777	09/08	8:18	N	660	
78	F06	Upstreamer	00778	09/08	19:31	S	620	
79	F06	Upstreamer	00779	09/09	10:22	N	690	
80	F06	Upstreamer	00780	09/09	17:00	N	610	
81	F06	Upstreamer	00781	09/10	8:43	S	700	
82	F06	Upstreamer	00782	09/10	19:29	N	560	
83	F10	Downstreamer	00783	09/11	9:12	N	670	
84	F06	Upstreamer	00784	09/11	18:05	N	630	
85	F06	Upstreamer	00785	09/12	7:40	N	710	
86	F06	Upstreamer	00786	09/12	20:05	S	560	
87	F06	Upstreamer	00787	09/13	11:35	N	530	
88	F06	Upstreamer	00788	09/13	17:55	N	680	
89	F07	Upstreamer	00789	09/14	9:26	N	670	
90	F06	Upstreamer	00790	09/14	20:05	S	630	
91	F06	Upstreamer	00791	09/15	13:06	S	670	
92	F06	Upstreamer	00792	09/15	19:16	N	640	
93	F06	Upstreamer	00793	09/16	11:11	N	670	
94	F06	Upstreamer	00794	09/16	16:13	N	640	
95	F06	Upstreamer	00795	09/17	9:32	N	700	
96	F06	Upstreamer	00796	09/17	18:22	N	600	
97	F06	Upstreamer	00797	09/18	8:10	N	670	
98	F06	Upstreamer	00798	09/18	20:07	N	650	
99	F06	Upstreamer	00799	09/19	8:55	N	630	
100	F06	Upstreamer	00100	09/19	16:48	N	680	
101	F06	Upstreamer	00101	09/20	13:00	N	700	
102	F10	Downstreamer	00102	09/20	17:16	S	630	
103	F06	Upstreamer	00103	09/21	9:42	N	660	
104	F06	Upstreamer	00104	09/21	17:25	N	590	
105	F06	Upstreamer	00105	09/22	7:57	S	670	
106	F06	Upstreamer	00106	09/22	16:01	N	520	
107	F06	Upstreamer	00107	09/23	9:41	N	640	
108	F06	Upstreamer	00108	09/23	17:14	N	680	
109	F06	Upstreamer	00109	09/24	10:04	N	750	
110	F06	Upstreamer	00110	09/24	19:05	N	650	
111	F06	Upstreamer	00111	09/25	10:03	S	600	
112	F06	Upstreamer	00112	09/25	15:54	N	700	
113	F06	Upstreamer	00113	09/26	8:38	N	680	
114	F06	Upstreamer	00114	09/26	19:04	N	650	
115	F06	Upstreamer	00115	09/27	10:32	N	690	
116	F06	Upstreamer	00116	09/27	19:29	N	570	
117	F10	Downstreamer	00117	09/28	8:28	N	630	
118	F06	Upstreamer	00118	09/28	16:23	N	680	
119	F06	Upstreamer	00119	09/29	8:20	N	680	
120	F06	Upstreamer	00120	09/29	16:44	N	630	
121	F06	Upstreamer	00121	09/30	11:00	N	710	
122	F06	Upstreamer	00122	09/30	17:19	N	590	

Average Days

[a] Experimental fate relative to the mark-recapture experiment and the recapture reach. "Downstreamers" moved downstream after marking and never returned to approach or enter the recapture reach while "upstreamers" moved upstream into the recapture reach

[b] Days elapsed between capture and entry into the recapture reach as detected by the fixed telemetry station at the lower boundary of the recapture reach.