Fishery Data Series No. 11-12

Inriver Abundance and Distribution of Spawning Susitna River Sockeye Salmon *Oncorhynchus nerka*, 2008

by

Richard J. Yanusz,

Richard A. Merizon,

T. Mark Willette,

David G. Evans,

and

Ted R. Spencer

May 2011

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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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)

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

FISHERY DATA SERIES NO. 11-12

INRIVER ABUNDANCE AND DISTRIBUTION OF SPAWNING SUSITNA RIVER SOCKEYE SALMON *ONCORHYNCHUS NERKA*, 2008

by
Richard J. Yanusz
Alaska Department of Fish and Game, Division of Sport Fish, Palmer

Richard A. Merizon
Alaska Department of Fish and Game, Division of Sport Fish, Palmer

T. Mark Willette
Alaska Department of Fish and Game, Division of Commercial Fisheries, Soldotna

David G. Evans
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage

and

Ted R. Spencer
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

May 2011

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Richard J. Yanusz
Alaska Department of Fish and Game, Division of Sport Fish
1800 Glenn Highway, Suite 4, Palmer, AK 99645-6736, USA

Richard A. Merizon
Alaska Department of Fish and Game, Division of Sport Fish
1800 Glenn Highway, Suite 4, Palmer, AK 99645-6736, USA

T. Mark Willette
Alaska Department of Fish and Game, Division of Commercial Fisheries,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276, USA

David G. Evans
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, AK 99518-1565, USA
and
Ted R. Spencer
Alaska Department of Fish and Game, Division of Commercial Fisheries
333 Raspberry Road, Anchorage, AK 99518-1565, USA

This document should be cited as:
Yanusz, R. J., R. A Merizon, T. M. Willette, D. G. Evans, and T. R. Spencer. 2011. Inriver abundance and distribution of spawning Susitna River sockeye salmon Oncorhynchus nerka, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 11-12, Anchorage.

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ABSTRACT

In 2008, a capture-recapture experiment was conducted using radio tags, fish wheels, and weirs to estimate the sockeye salmon escapement to the entire Susitna River drainage. Radio tags were used as the mark in the abundance experiment and to identify spawning locations of adult sockeye salmon ≥400 mm mid eye to fork of tail. Two separate abundance estimates were calculated; one for the Yentna River system upstream of the Yentna sonar (Yentna river kilometer [rkm] 7) and one for the Susitna River system upstream of Sunshine (Susitna rkm 116). The partially stratified estimate for the abundance of sockeye salmon passing Yentna sonar is 288,988 (95% CI 251,436-326,540). The partially stratified abundance estimate for sockeye salmon passing Sunshine is 70,552 (95% CI 60,882-80,221), making total abundance of the sockeye salmon escapement in the entire Susitna River drainage 359,540 (95% CI 320,763-398,317), with 80% of the total migrating up the Yentna River system and 20% migrating up the Susitna River system above Sunshine. Forty eight percent (SE=2.6%) of the sockeye salmon escapement in the entire Susitna River drainage had final locations not associated with a major lake. The Bendix sonar-fish wheel estimate of the sockeye salmon escapement of 90,146 at Yentna sonar was biased low, as it was significantly less than the capture-recapture abundance estimate and also less than the sum of the weir counts in the Yentna River system (130,394). The DIDSON sonar-fish wheel estimate at Yentna was also very likely biased low, as it (131,772) was only about 1,400 fish more than the sum of the Yentna River system weir counts while 52% (SE = 2.9%) of radiotagged sockeye salmon in the Yentna River system did not enter a major lake in 2008.

Key words: sockeye salmon, Susitna River, Yentna River, escapement, abundance, capture-recapture, fish wheel, weir, sonar, radiotelemetry, spawning

INTRODUCTION

The Susitna River is a major contributor to the sockeye salmon *Oncorhynchus nerka* run in upper Cook Inlet. In 2008, management of the Susitna River sockeye salmon run was based on an estimate of the escapement of sockeye salmon into the Yentna River, a major tributary of the Susitna River (Figure 1). This estimate was calculated as the product of a Bendix sonar count of the escapement of all fish into the Yentna River and the proportion of sockeye salmon in fish wheel catches (Westerman and Willette 2007). The sustainable escapement goal range (SEG) in effect in 2008 was 90,000-160,000 Yentna River sockeye salmon (Hasbrouck and Edmundson 2007). The sockeye salmon escapement to the entire Susitna River drainage was assumed to be 1.95 times the Yentna River escapement, as calculated above (Tobias and Willette 2004). The basis for this expansion factor was a combination of capture-recapture abundance estimates of sockeye salmon passing Sunshine (Susitna River at river kilometer [rkm] 116) and Bendix sonar-fish wheel estimates of sockeye salmon passing Yentna (Yentna River, rkm 7) and Susitna Station (Susitna River, rkm 45) during 1981-1985 (Fox 1998).

Between 1999 and 2005, estimated sockeye salmon escapements for the Yentna River were below the SEG 5 of 7 years. Part of the Alaska Department of Fish and Game (ADF&G) response to this situation was to examine the accuracy of the Yentna River sonar-fish wheel escapement method and reexamine the relationship of the sockeye salmon escapement in the Yentna River to the sockeye salmon escapement in the entire Susitna drainage. ADF&G, with participation from the Cook Inlet Aquaculture Association (CIAA), began a study in 2006 to estimate the sockeye salmon escapement in the entire Susitna River drainage using capture-recapture experiments that were independent of the sonar-fish wheel estimate. The independent escapement estimates were designed to allow: (1) estimation of the total annual run of Susitna River sockeye salmon by summing the escapement estimates with commercial catch estimates derived from genetics-based, stock-separation techniques, (2) evaluation of the accuracy of the Yentna River sockeye salmon sonar-fish wheel estimate, and (3) estimation of the proportion the Yentna River contributes to the sockeye salmon escapement in the entire Susitna River drainage.

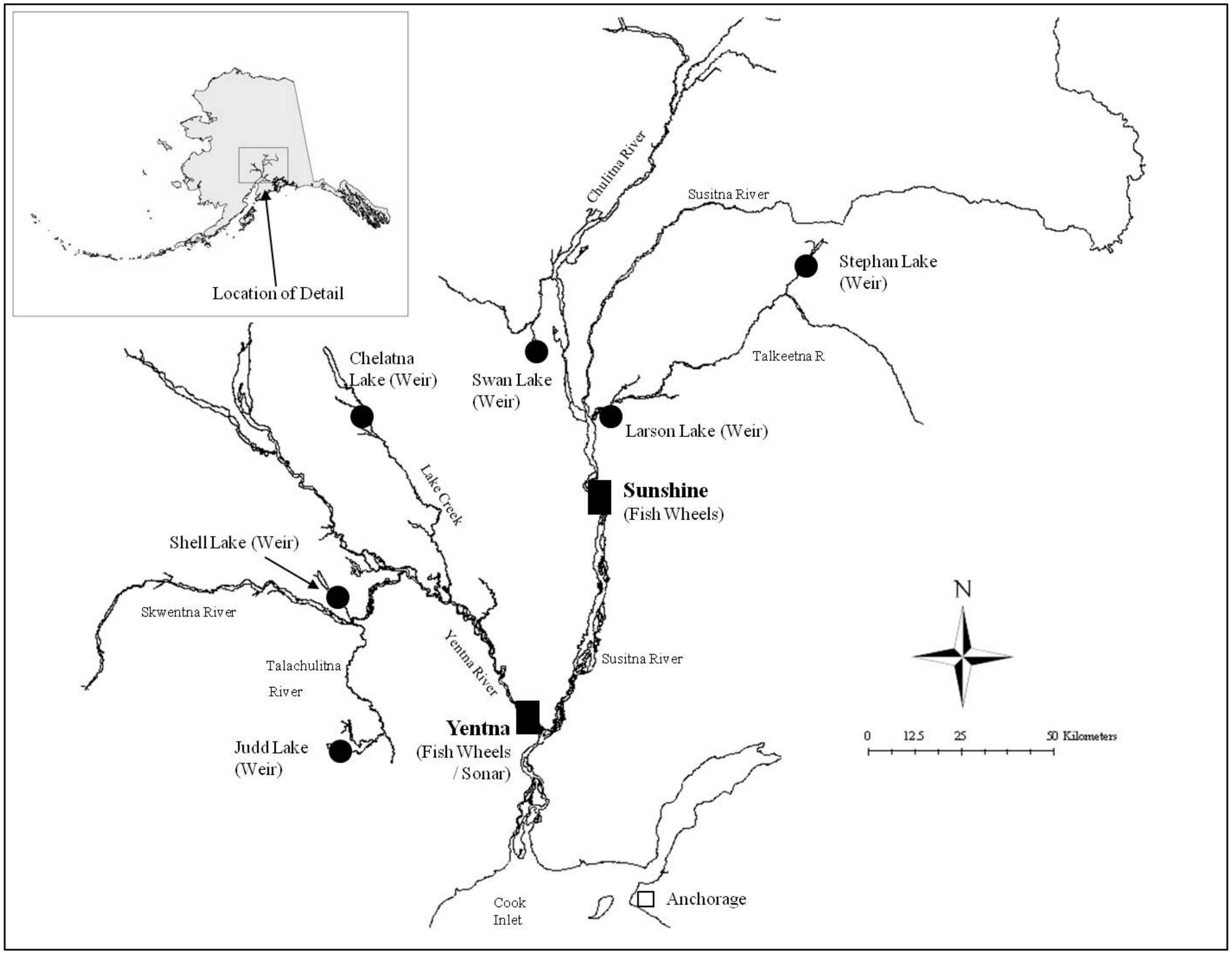


Figure 1.-Locations of fish wheels, sonar, and weirs in Susitna River drainage, 2008.

In 2006, fish wheels at three sites and weirs at six lakes were used to capture and recapture sockeye salmon marked with passive integrated transponder (PIT) tags, radio tags, and finclips. Abundance estimates of sockeye salmon for the Susitna River system above Sunshine and for the Yentna River system were generated, but had unresolved uncertainties due to possible tag loss, poor tag detection, tagging effects, and low sample sizes (Yanusz et al. 2007). Many new spawning locations were documented throughout the Susitna River drainage. In 2007, Susitna River sockeye salmon were marked with radio tags and finclips at fish wheels at two sites, one in the lower Yentna River and the other at Sunshine in the lower Susitna River. Marks (radio tags) were recovered at seven lakes. Abundance estimates of sockeye salmon were generated independently; approximately 240,000 fish for the Yentna River system and approximately 88,000 fish for the Susitna River system above Sunshine (Yanusz et al. *In prep*). Flooding of the Chelatna Lake weir compromised the Yentna River system estimate to some extent.

The objectives in 2008 were to estimate the inriver abundance of adult Susitna River sockeye salmon migrating upstream of Yentna and Sunshine (escapement) using capture-recapture experiments (Figure 1) based on radio tags, and to identify additional sockeye salmon spawning areas throughout the Susitna River drainage using radiotelemetry. A new floating weir was used at Chelatna Lake in 2008 in the hopes that it would remain functional through high water events.

STUDY AREA

The Susitna River drainage comprises 49,210 km^2 and it originates in the Alaska Range north of Anchorage (Figure 1). Susitna River flows generally south from the Alaska Range for approximately 400 km before entering upper Cook Inlet west of Anchorage. The largest tributaries are the Yentna, Chulitna, and Talkeetna rivers, and there are numerous sockeye salmon nursery lakes. Most of the sockeye salmon produced within the Talkeetna River system are thought to come from Larson and Stephan lakes. Many small lakes contribute to sockeye salmon production in the Chulitna River system, but Byers and Swan lakes are believed to be the major producers. The Yentna River system has at least 12 lakes known to support sockeye salmon, of which Chelatna, Shell, Hewitt, and Judd lakes are thought to provide the most production potential (King and Walker 1997).

METHODS

ABUNDANCE

Separate, two-event, capture-recapture experiments were used to estimate the abundance of adult sockeye salmon (Seber 1982) for the Susitna River system upstream of Sunshine and the Yentna River system.

Capture Events

Two fish wheels, one on each bank, were operated at both Yentna (the location of the sonar site) and Sunshine (Figure 1). Each fish wheel had 2×2 m baskets that were adjusted as needed to fish ≤0.3 m from the river bottom. Picket weirs, installed between the fish wheel and the river bank, were operated at Yentna and Sunshine for the entire season (Table 1). At Sunshine, fish wheels were fished for two, 3 h periods spaced 5 h apart during daylight hours, for a total of 6 h of effort per day. The start fishing time for the fish wheel each day was systematically rotated, so that over the course of 5 d most daylight hours were sampled. At Yentna, to be consistent with the historic sonar-fish wheel methods, fish wheels were operated for three, 2 h periods, for a total of

Table 1.-Fish wheel locations and operating dates in Susitna River drainage, 2008.

	River kilometer (rkm)			Riverbanks	Dates of operation			
					Fish wheel weir		Fish wheel	
Location [a]	Susitna R	Yentna R	Site name	fished	Installed	Removed	Started	Stopped
Lower Susitna River tributary -								
Susitna-Yentna river confluence	45 [b]	0	Yentna	North bank	7/7	8/10	7/7	8/10
Yentna River sonar/fish wheels	na	7		South bank	7/7	8/10	7/7	8/10
Lower Susitna River								
mainstem fishwheels,	116	na	Sunshine	West bank	7/5	8/12	7/5	8/12
about 12 km below the George				East bank	7/5	8/12	7/5	8/12
Parks Highway bridge (rkm 128)[b]								

Note: na = not applicable.

[a] Thompson et al. (1986) defined "lower Susitna River" as the river reach between Susitna River confluence at Cook Inlet (river mile [RM] 0.0 [river kilometer (rkm) 0.0]) and the Susitna-Chulitna river confluence (RM 98.6 [rkm 158.7]) near Talkeetna.

[b] River kilometer (rkm) conversion from river miles (RM) presented in Thompson et al. (1986).

6 h of effort per day. A 2 h period was selected from within each of the following 3 periods: 0600-1200, 1200-1800, and 1800-2400. At both fish wheel capture sites it was assumed that there was no substantial diel variation in the stock composition of fish passage.

Fish wheels were checked at least once per hour during each sampling period. Only uninjured sockeye salmon ≥400 mm mid eye to tail fork length (METF) were radiotagged. Sockeye salmon <400 mm METF[1] were not radiotagged because these smaller fish may not have the same capture probability at fish wheels or weirs as larger fish. To minimize handling effects, sockeye salmon receiving a radio tag were taken directly out of the fish wheel basket as they were captured and tagged immediately. Every 10th sockeye salmon caught in the north and south bank fish wheels at Yentna was radiotagged. Every 5th and 15th sockeye salmon caught on the west and east banks at Sunshine, respectively, were radiotagged. Fish were tagged at a higher rate on the west bank because the 2007 study (Yanusz et al., *In prep)* found (a) a lower capture probability for the west bank fish wheel, and (b) a smaller population migrating along the west bank compared to the east bank. The chosen rates were designed to mitigate the difference in capture probabilities and also to ensure enough radio tags were applied on the west bank to yield meaningful distribution data for west bank oriented populations. Sockeye salmon present in the live box at the beginning of a fish wheel visit were counted and released. Radio tags were applied to every subsequent fish caught while the crew was present until the appropriate radio tagging rate for that fish wheel was achieved. Every nth (n=5th, 10th, or 15th, depending on the fish wheel) sockeye salmon caught thereafter while the crew was present was radiotagged. Radiotagged fish were also measured for METF, sex was determined from external morphological characteristics[2], and a tissue sample (left axillary process) was collected from each using standard ADF&G Genetics Conservation Lab procedures[3] and preserved in ethanol for genetic assay. To minimize holding time, no anesthesia was used, fish were held in tubs with fresh river water, fish were restrained in padded cradles during tagging and no scale was sampled. Handling time of radiotagged fish averaged ≤1.5 min.

The radio transmitters used were manufactured by Advanced Telemetry Systems, Inc.[4] (ATS™) and operated on 19 frequencies within the 150.000 to 150.999 MHz range. Each frequency had 50 different transmitting patterns (i.e., pulse codes), resulting in 950 uniquely identifiable transmitters available. All transmitters were 42×17 mm cylinders equipped with a 30 cm antenna, and each weighed 14 g. The minimum battery life of the transmitters was 120 d. Each transmitter was equipped with an activity monitor as a mortality indicator. The activity monitor changed the signal pattern to an inactive mode (Eiler 1995) if the transmitter was stationary for 24 h. Radio tags were inserted through the esophagus and into the upper stomach of the fish using a 10 mm diameter, 30 cm long plastic tube.

Sockeye salmon captured at Yentna and Sunshine fish wheels that were not radiotagged were sampled for scales (for age determination), sex, and METF (ASL). At Sunshine, the left axillary process was also clipped from each ASL sampled fish and stored in bulk in ethanol for genetic assay. ASL samples at Sunshine were collected in a batch at the beginning of each day's shift.

---

1 Sockeye salmon <400 mm METF are usually "jacks." Jacks are male sockeye salmon that spend only one winter at sea before they return to freshwater. Historically, jacks make up about 1% of the Susitna River sockeye salmon run (Tobias and Willette 2004).

2 Coloration, body and fin shape, and jaw morphology are secondary sexual characteristics used to differentiate the sex of live Pacific salmon.

3 Source: ADF&G. 2008. Sampling non-lethal finfish tissues for DNA analysis. Genetics Conservation Lab, Anchorage. http://www.adfg.alaska.gov/static/fishing/PDFs/research/salmon_sampling_instructions.pdf (Accessed 5 May 2008).

4 Product names used in this publication are included for completeness but do not constitute product endorsement.

ASL sampling at Yentna followed the ADF&G Division of Commercial Fisheries historical ASL sampling procedures, collected in proportion to the previous day's sonar estimate of sockeye salmon abundance, to achieve a minimum total sample of 500 scales over the season (*Unpublished* ADF&G Division of Commercial Fisheries operational plan for upper Cook Inlet commercial [salmon] catch and escapement sampling obtained from T. Tobias, Fishery Technician, ADF&G, Soldotna). At Yentna, the left axillary process was clipped and preserved from only radiotagged fish, as this provided sufficient samples for genetic analysis.

For age determination, one scale was removed from the preferred area and scales were placed on labeled gum cards (Clutter and Whitesel 1956). In the laboratory, the gum cards were impressed in heated acetate cards and the ages designated by examining the scale circuli patterns under magnification.

Recapture Events

CIAA counted sockeye salmon passing through weirs at Chelatna, Shell, and Judd lakes in the Yentna River system, and Swan, Stephan, and Larson lakes in the Susitna River system above Sunshine (Figure 1). An automated radiotelemetry station was placed adjacent to each weir to count the number of radiotagged fish. See "Radio Tag Distribution and Migration Timing" below for details. ASL data were collected throughout the runs from samples of sockeye salmon trapped at each weir. All sockeye salmon within each trap load were sampled to minimize selection bias.

Estimation of Abundance

Abundance of sockeye salmon migrating into the entire Susitna River drainage was estimated as the sum of two, independent, 2-event, closed population, capture-recapture experiments. Each experiment represented a separate component of the entire run, one being the migration past the Yentna sonar site and the other the migration past Sunshine.

Yentna River System Abundance

If assumptions *a-d* below were met, then Chapman's modification of the Petersen model (Seber 1982) was used to estimate abundance $\hat{N}$ for an experiment such that:

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

where M is the number of fish captured and marked during event 1, C is the number of fish inspected for marks during event 2, and R is the number of C that possessed marks applied during event 1. The variance of the abundance estimate was estimated as:

$$\mathrm{var}(\hat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}. \tag{2}$$

The conditions necessary for Equation 1 to provide an accurate estimate of abundance are described in Seber (1982):

(a) every fish has an equal probability of being marked in event 1, or every fish has an equal probability of being inspected for marks in event 2, or marked fish are mixed completely with unmarked fish between events; and

(b) there are no mark induced behaviors (including tag induced mortality); and

(c) fish did not lose their marks between events and all marks are recognizable; and

(d) there is no immigration or mortality (emigration) between events.

To address the equal probability of marking provision of condition *a*, fish wheels were run concurrently on both banks throughout the migration and fish were tagged at the same rate within a bank. The fish wheels were run 6 h/d on each bank at each site, with starting times staggered within daylight hours through the season to improve the chances that each component of the run was exposed to marking. Fish wheels tend to capture more sockeye salmon as more fish pass by, resulting in self weighting of tag deployment over time.

To test whether condition *a* was met, two Chi-square (χ^2) tests were performed with the following null hypotheses: (1) the ratios of marked to unmarked fish in samples from event 2 were constant over recovery strata (time or weir), and (2) the ratio of recaptured versus not recaptured fish was constant over marking strata (time or bank). If the null hypothesis of either test was not rejected, the pooled abundance estimate (Equation 1) was considered sufficient, with consideration of the caveats described in Schwarz and Taylor (1998); otherwise, a temporally or spatially partially stratified estimate was considered using the Stratified Population Analysis System (SPAS) software program (Arnason et al. 1996). Banks and weirs comprised natural spatial strata with respect to tagging and recovery, respectively. The χ^2 and G^2 goodness of fit statistics provided by SPAS were used to evaluate model fit in the partially stratified analysis (Arnason et al. 1996). Factors considered when evaluating strata to pool were: (1) eliminating strata with recaptures of <5, (2) pooling adjacent strata with similar initial capture or recapture probabilities, and (3) minimizing the standard error of the estimate. If a large change occurred in the G^2 statistic or standard error (i.e., greater than 1 SE) during pooling, the abundance estimate was considered questionable and dropped (Arnason et al. 1996).

At Yentna fish wheels, the ratio of fish wheel catch of all salmon species to the DIDSON (dual frequency identification sonar) count of all species of salmon over time for each bank was also examined to indicate if the fish wheels on each bank fished with consistent efficiency as an additional test of condition *a*. This test assumes the sonar is counting at least a certain proportion of the passage of all species.

With respect to the provision in condition *a* of equal inspection probabilities for event 2 , the probability of capture for fish entering each of the weirs while operating was 1.0 (or close to it), while the probability of recapture of those fish spawning in areas outside of the lakes with weirs was zero. Equal inspection probabilities for event 2 were therefore precluded as a function of the design of the experiment and the Chapman-Petersen estimate relied on equal capture probabilities at the fish wheels.

Because the equal probability of capture provision of condition *a* is relevant to attributes other than when and where salmon are captured, the possibility of size selective sampling was investigated. The hypothesis that fish of different sizes were captured with equal probability in event 1 was tested using a Kolmogorov-Smirnov (K-S) two-sample test ($\alpha = 0.05$) to compare size distributions of fish captured in the second event with that of recaptured fish. The hypothesis that fish of different sizes were captured with equal probability in event 2 was tested using a K-S two-sample test ($\alpha = 0.05$) to compare size distributions of marked and recaptured fish.

Condition *b* was tested using radiotelemetry. The proportion of radiotagged fish that did not resume upstream migration after tagging was assumed to be an estimate of tag induced mortality. Radiotagged fish failing to resume upstream migration were culled from the study. Bank effects on the tendency for radiotagged fish to sustain upstream migration after tagging were tested with a 2×2 - χ^2 test of independence between bank of marking and migration status (up or down).

The tag loss component of condition *c* was indistinguishable from tag induced mortality as it manifested itself in downstream or stationary radio relocations and was accounted for on that basis. The tag detection component of condition *c* was addressed by using redundant methods (tracking stations plus aerial surveys) and by comparing the number of tags deployed versus the number detected. Condition *d* was assumed to be met for fish tagged at all sites because there were no other sources of salmon entering the river upstream of these sites (immigration), there were no large, inriver sockeye salmon fisheries in the Susitna River (mortality and emigration), and nearly the entire Susitna River drainage was the study area, so leaving the study area was extremely limited (emigration). Movement between the two experiments was monitored by radiotelemetry.

Susitna River System above Sunshine Abundance

At the Sunshine fish wheels in 2008, the tagging rate on the west bank was every 5th fish caught, compared to every 15th fish caught on the east bank (see Capture Event above), in part to allow for a more precise estimation of the distribution of west-bank oriented fish. This differential tagging strategy meant that a partially stratified abundance estimator would likely be more appropriate than the pooled estimator described above (Equation 1). The same estimator selection techniques were used as described above. It is possible that the differential tagging rates conspired with differential probability of capture to mark the east and west bank populations equally, leaving the pooled estimator as the more appropriate.

RADIO TAG DISTRIBUTION AND MIGRATION TIMING

River Tracking Stations

Radiotagged sockeye salmon movement upriver was automatically recorded at 11 river tracking stations placed on major tributaries throughout the Susitna River drainage (Table 2; Figure 2). The Flathorn tracking station was placed below both tagging sites to monitor fish migrating downstream after tagging.

Table 2.-Locations of tracking stations used to monitor the movements of radiotagged Susitna River sockeye salmon, 2008.

	Tracking station			Distance (rkm) from:	
		Type			Previous
Area description	Name	River	Weir	Saltwater	station
Susitna River drainage:					
Lower Susitna R mainstem	Flathorn	X		40.0	na
Lower Susinta R tributary					
Yentna R mainstem	Lower Yentna River	X		58.1	18.1 [a]
Yentna R tributary	Kahiltna River	X		93.7	35.6
Kahiltna R drainage lake	Chelatna Lake		X	184.9	126.9
Yentna R tributary	Skwentna River	X		138.5	80.4
Skwentna R drainage lake	Shell Lake		X	151.5	13.0
Yentna R tributary	Talachulitna River	X		144.9	6.4
Talachulitna R drainage lake	Judd Lake		X	221.2	76.3
Yentna R tributary	Kichatna River	X		147.3	89.2
Kichatna R drainage lake	Upper Yentna River	X		156.0	98.0
Lower Susinta R mainstem	Sunshine	X		128.3	88.3 [a]
Susitna R tributary	Talkeetna River	X		156.6	28.3
Talkeetna R drainage lake	Larson Lake		X	170.9	14.3
Talkeetna R tributary lake	Stephan Lake		X	245.2	88.6
Susitna R tributary	Chulitna River	X		170.7	42.4
Chulitna R tributary lake	Swan Lake		X	216.5	45.8
Middle Susinta R [b] mainstem	Middle Susitna River	X		165.0	36.7

Note: na = not applicable.

[a] Distance from previous station calculated from Flathorn (rkm 40).

[b] Historically the "middle Susitna River" has been defined as the river reach between Susitna-Chulitna river confluence (RM 98.6 [rkm 158.7]) and Devils Canyon (RM 152.0 [rkm 244.6])(Thompson et al. 1986).

Tracking station equipment consisted of an ATS Model 4500 receiver and data logger and a self contained power system. A satellite uplink (Campbell Scientific, Logan, Utah) was used for all of the river tracking stations except Sunshine. The equipment was housed in an enclosure and attached to a 9 m mast.

An ATS Model 200 antenna switch was coupled with two antennas at each tracking station. One antenna was oriented downstream, and the other upstream. Signal strength and time of reception were recorded separately for each antenna and provided information on direction of travel. "Reference" radio tags were continuously detected at each station to assure proper station operation. Information was recorded at 10 min intervals.

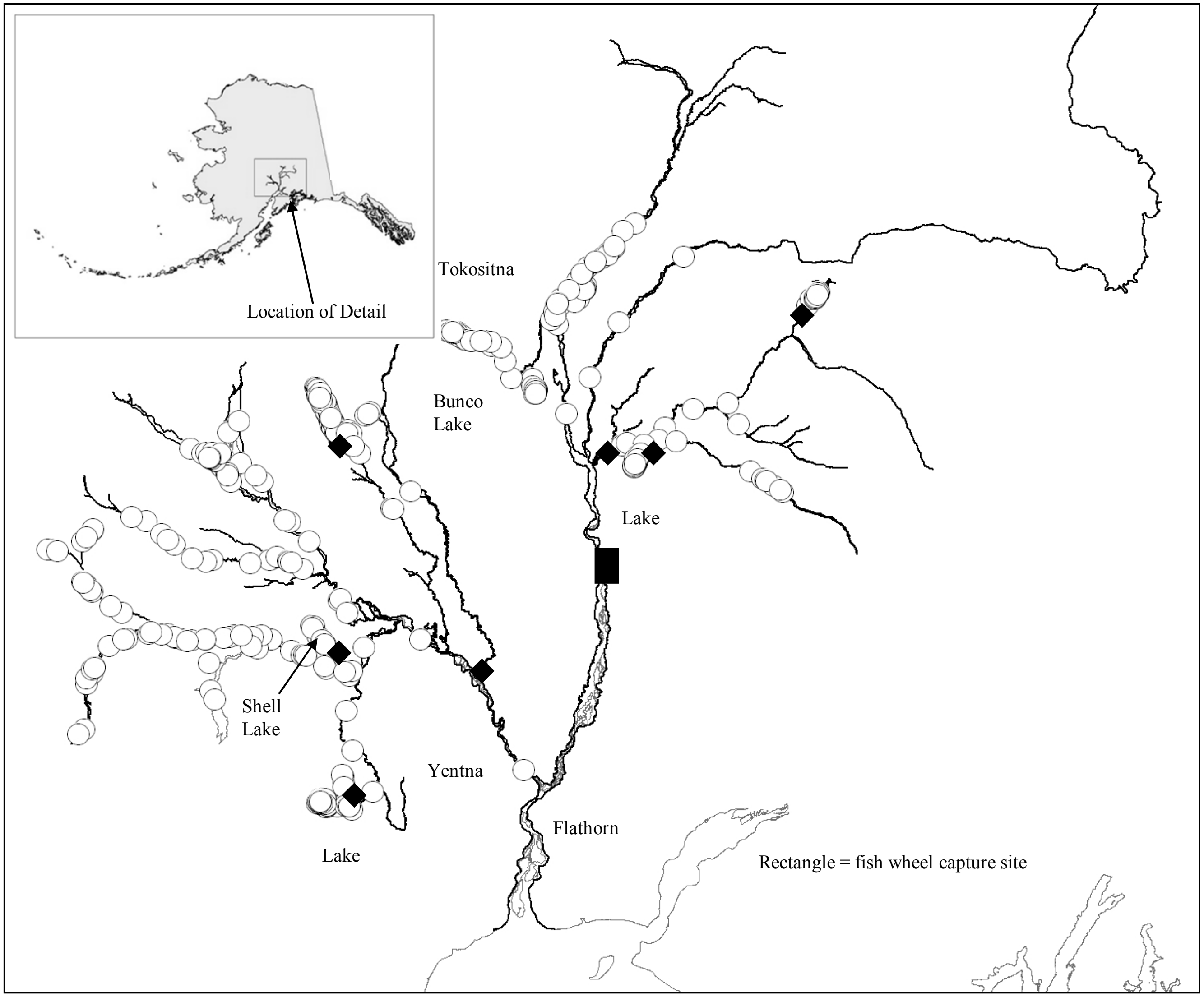


Figure 2.-Locations of fish wheel capture sites, weirs, and radiotracking stations in Susitna River drainage, and the terminal distribution of radiotagged sockeye salmon based on aerial surveys, 2008.

The ATS receiver detected radiotagged fish and recorded signal strength, activity pattern of the transmitter (active or inactive), date, time, and location of each fish in relation to the station (i.e., upriver or downriver from the site). Radiotagged fish were considered to have passed a tracking station when the recorded signal strength indicated the transition from the downriver antenna to the upriver antenna. The first tracking stations were located approximately 5 km upriver from the tagging sites.

Because most of the river tracking stations were located in isolated areas, data were transmitted every hour by satellite uplink to a geostationary operational environmental satellite system and relayed to a receiving station near Washington, D.C. (Eiler 1995). Data transmissions were monitored during the field season via the internet. Tracking stations easily accessible by road or boat were visited every 1-2 weeks, and data were downloaded as a comma delimited file to a laptop computer using Microsoft™ compatible software from ATS™. After the field season, data from isolated stations were also downloaded in this way. Each record in the file contained site code, download date and time, radio frequency and pulse code, date and time of detection, antenna number, and signal strength.

Weir Tracking Stations

Radiotagged sockeye salmon movement upriver and into lakes was also tracked at six weir stations. These stations were similarly equipped as river tracking stations except for a shorter, 3 m mast and no satellite uplink.

Because many of the weir sites were located close to a lake's outlet, determining passage time was occasionally difficult. While the signal strength of radiotagged sockeye salmon arriving at weirs was very high, some fish lingered just below or just above the lake outlet. The lack of a rapid drop off in signal strength due to this lingering behavior made the transition from the lower antenna to the upper antenna difficult to determine for some individuals. When necessary, aerial surveys and later tracking station records for affected fish were compared when selecting a date of fish passage into each lake.

Each weir tracking station was visited every 7-10 d and data were downloaded as a comma delimited file to a laptop computer. This information was stored in the Palmer and Anchorage ADF&G offices for postseason analysis.

Aerial Surveys

A fixed-wing aircraft was used to conduct aerial surveys of the entire Susitna River drainage. The aircraft was equipped with an ATS Model 4500 receiver and data logger and two, 4-element Yagi receiving antennas, one mounted on each side of the aircraft and oriented forward. Aerial tracking receivers contained an integrated global positioning system (GPS) to identify and record locations. Automatically recorded data included: date and time of decoding, frequency and pulse code, latitude and longitude, signal strength, and activity mode of each decoded transmitter. At the Palmer or Anchorage ADF&G office, data were downloaded as a comma delimited file to a desktop computer using Microsoft™ compatible software from ATS™. Data for each survey were imported to Microsoft™ Excel and sorted by frequency, pulse code, and time. For each tag, the location with the greatest signal strength was chosen as the most likely location of the tagged fish. Data were also recorded on a form during the survey as a backup to the automated recording system and to track the number of radio tags detected during each survey.

Estimation of Spawning Distribution

Assuming the population migrating past each fish wheel tagging site (Yentna or Susitna) was proportionally tagged, the proportion of the population destined for probable spawning location *i* was estimated as:

$$\hat{p}_i = \frac{r_i}{r} \tag{3}$$

where:

r_i = number of radio tags out of r assumed to have spawned in location i, and

r = number of radio tags released from the marking site that retained upstream migration and was assigned to a probable spawning location.

An estimate of the variance of $\hat{p}_i$ is given by:

$$\mathrm{var}(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{(r-1)} \tag{4}$$

If the assumption of proportional tagging was not met, bank specific distributions using the equations above were estimated, but with *r* being the number of radio tags released from a specific bank at the marking site that resumed upstream migration and was tracked to a probable spawning location.

If the assumption of proportional tagging was not met, but a partially-stratified estimator was available that yielded precise estimates of bank specific abundance, the distribution data were weighted accordingly to yield a drainage-wide distribution.

For the Susitna River system above Sunshine, the weighted distribution for area *i* was estimated as follows:

$$\hat{p}_i = \hat{p}_{iW} \frac{\hat{N}_W}{\hat{N}_W + \hat{N}_E} + \hat{p}_{iE} \frac{\hat{N}_E}{\hat{N}_W + \hat{N}_E} \tag{5}$$

where:

$\hat{p}_{iW}$ = proportion of tags applied on the west bank that migrated to probable spawning location i;

and similarly for $\hat{p}_{iE}$,

$\hat{N}_W$ = Darroch-derived estimate of abundance on the west bank; similarly for $\hat{N}_E$.

Estimation of the variance of $\hat{p}_i$ is complicated by covariances among the components in Equation 5. The standard error of the (weighted) distribution proportion $\hat{p}_i$ in Equation 5 was derived through simulation. For the west wheel component of each simulation, 76 radio tags were distributed among the categorized spawning sites (8 of them) as a multinomial random variable; the multinomial 'p' parameter vector (length = 8) was taken as the set of proportions of the 76 tags found in the 8 areas in 2008. For the east wheel component, 148 tags were distributed similarly. Bank-specific Darroch least squares estimates of abundance were then calculated from each set of generated recaptures according to the formulas in Schwarz and Taylor (1998). A simulated set of $\hat{p}_{iW}$ and $\hat{p}_{iE}$ was then calculated and Equation 5 used to calculate a simulated $\hat{p}_i$. The standard error of $\hat{p}_i$ was then taken as the sample variance of the simulated $\hat{p}_i$'s over all simulations.

An identical procedure was followed for the Yentna River system, with 81 and 255 radio tags distributed according to multinomial vectors calculated for the north and south banks, respectively.

Estimation of Migration Timing and Rates

Migration (run) timing analysis for a given spawning location *i* within a river system was based on the time radio tags destined for location *i* passed the marking site. Because the fish wheel capture and marking sites in the Yentna River system and the Susitna River system above Sunshine differed with respect to how far upstream each was located, run timing of stocks within but not between systems could be compared. Median timing was calculated for each location using standard methods.

Travel rates for radiotagged sockeye salmon were calculated using the date and time fish passed between tracking stations, along with river distance between them.

RESULTS

In 2008, fish wheels were operated from 5 July to 12 August at Sunshine and from 7 July to 10 August at Yentna, during which each fish wheel operated for an average of 6 h/d (Appendices A1-A2). The total catch at the Sunshine fish wheels was 3,201 sockeye salmon, of which 253 were radiotagged (Appendix A1). At Yentna, a total of 3,429 sockeye salmon were caught, of which 354 were radiotagged (Appendix A2). Twenty-eight coho salmon were radiotagged in error at Sunshine (identified postseason by genetic analysis). All tagged coho salmon were removed from the analysis, and no adjustments were incorporated in the abundance estimate to account for the variation in tagging rate.

Seventeen radiotagged fish from the Sunshine releases and nine radiotagged fish from the Yentna releases were assumed to be injured by the tagging process and these tags were removed from the set of marks used in the abundance and distribution estimates. Of the 17 tags removed from the Sunshine dataset, 7 were never detected again by tracking stations and 10 did not sustain any significant upstream migration beyond the marking site; of the 9 tags removed from the Yentna dataset, 1 was never detected again by tracking stations and 8 did not sustain any significant upstream migration beyond the marking site. After the removal of all radiotagged fish that did not continue their upstream migration after being tagged, a total of 236 marks were available for recapture and terminal distribution determination from Sunshine (158 from the east bank fish wheel and 78 from the west bank fish wheel, Table 3), and a total of 345 marks were available for recapture and terminal distribution determination from Yentna (84 from the north bank fish wheel and 261 from the south bank fish wheel, Table 3).

The total catch of other salmon species at fish wheel sites in 2008 included: 94 Chinook *O. tshawytscha*, 3,132 coho *O. kisutch*, 4,537 pink *O. gorbuscha*, and 1,595 chum *O. keta* salmon caught at Sunshine (Appendix A1) and 17 Chinook, 1,546 coho, 7,193 pink, and 542 chum salmon caught at Yentna (Appendix A2).

Table 3.-Capture, marking, and recapture of Susitna River sockeye salmon, 2008.

Capture		Marking			Recapture						
					Yentna R system			Susitna R system above Sunshine			
Site	Fish wheel	Initial number captured & marked [a]	Discounted marks [b]	Final number of analyzed marks [c]	Chelatna Lk weir [d]	Judd Lk weir	Shell Lk weir	Larson Lk weir	Stephan Lk weir	Swan Lk weir	Total
Sunshine	East bank [e]	170	12	158				85	14	6	105
	West bank [e]	83	5	78				4	0	16	20
	Total [e]	253	17	236				89	14	22	125
	Weir count							34,516	4,990	4,037	43,543
	Marked ratio							0.0026	0.0028	0.0055	0.0029
Yentna	North bank [e]	87	3	84	30	5	0			1	36
	South bank [e]	267	6	261	52	62	10				124
	Total [e]	354	9	345	82	67	10			1	160
	Weir count				73,469	54,301	2,624				130,394
	Marked ratio				0.0011	0.0012	0.0038				0.0012

[a] Marked = radiotagged.

[b] These radiotagged fish were removed from the set of marks used in the abundance and distribution estimates. Marks were discounted if the radiotagged fish were never detected by a tracking station after being tagged, if they moved downstream (i.e. detected at the Flathorn river tracking station), or if they failed to move upstream after being radiotagged.

[c] These radiotagged fish were included in the set of marks used in the abundance and distribution estimates.

[d] Radio tags detected by tracking station for entire season past the weir only. Total number of radiotagged sockeye salmon in the stream are not included.

[e] Units = number of radiotagged sockeye salmon.

Tissue samples were collected from 253 radiotagged sockeye salmon at Sunshine and 354 radiotagged sockeye salmon at Yentna in 2008. An additional 925 sockeye salmon tissue samples were collected at Sunshine.

In the Susitna River system above Sunshine, full-river picket weirs were operated at Larson, Stephan and Swan lakes between 8 July and 6 September (Appendix A3). In 2008, 34,516 sockeye salmon were counted through the Larson Lake weir, 4,990 through the Stephan Lake weir, and 4,037 through the Swan Lake weir, for a total weir count of 43,543 sockeye salmon in the Susitna River system above Sunshine. Tissue samples were collected from 200 sockeye salmon at Swan Lake and 196 at Stephan Lake.

Full-river picket weirs were operated at Judd, Shell, and Chelatna lakes in the Yentna River system between 10 July and 6 September (Appendix A3). During that period, 73,469 sockeye salmon were counted through the Chelatna Lake weir, 54,301 through the Judd Lake weir, and 2,624 through the Shell Lake weir, for a total weir count of 130,394 sockeye salmon in the Yentna River system.

Of the 236 radiotagged sockeye salmon released at Sunshine that remained in the study, 125 (53%) were detected passing through Larson (89), Stephan (14) and Swan (22) lake weirs (Table 3). Of the 345 radio tags released at Yentna that remained in the study, 159 (46%) were detected passing through Chelatna (82), Judd (67), or Shell (10) lake weirs (Table 3). A total of 285 of the 581 radio tags remaining in the study (49%) passed through the weirs in 2008. One radio tag released at Yentna passed through the Swan Lake weir in the Susitna River system above Sunshine. No tags released at Sunshine were detected at Yentna River system weirs.

ESTIMATION OF ABUNDANCE-SUSITNA RIVER SYSTEM ABOVE SUNSHINE

A K-S test of length distributions from weir samples versus recaptured radiotagged fish was significant ($P \approx 0$), suggesting probability of capture during marking was different among different size groups. The K-S test of length distributions from marked fish versus recaptured fish was not significant ($P = 0.86$), suggesting probability of capture in the recapture event was not different among different size groups, i.e., that the passage through the weirs was representative of the population by size. A difference was found in the length distributions of fish radiotagged by bank ($P = 0.02$); mean lengths of radiotagged fish on the east and west banks at Sunshine were 558 mm (SE = 3.1) and 570 mm (SE = 4.4), respectively. A K-S test of length distributions among untagged fish ($\geq$400 mm) among banks was not significant (K-S test: $P = 0.63$); the mean east bank length was 548 mm (SE = 2.5) and the mean west bank length was 551 mm (SE = 3.8). A K-S test of radiotagged versus untagged fish lengths on the east bank was not significant ($P = 0.17$), while the equivalent test for the west bank was significant ($P = 0.002$), suggesting some selectivity of caught fish for radio application on the west bank (larger fish receiving more radio tags). The age-1.2 versus age-1.3 composition of untagged fish did not differ significantly between banks ($P = 0.64$). An estimated 64% (SE = 2.2%) of the sampled untagged sockeye salmon at Sunshine were age-1.3 and 16% (SE = 1.7%) were age-1.2 (Table 4). As a result of these tests, the Susitna River system above Sunshine abundance estimate was not stratified by size.

The assessment of condition *a*, the "Mixing Test", which tests for equality of recaptured:not recaptured ratios over tagging strata (banks), was significant ($P = 0$); the "Equal Proportions" test, which tests the hypothesis of equal marked:unmarked ratios over recovery sites (weirs) was

Table 4.-Percent age composition of sockeye salmon sampled from fish wheels in 2008.

Location	Sample size [b]	Percent composition by age class [a]				
		Age 1.2	Age 1.3	Age 2.2	Age 2.3	Other
Yentna River - mainstem						
(Yentna fish wheels)	383	11.7	55.9	7.6	13.8	11.0
		(1.6)	(2.5)	(1.4)	(1.8)	(1.6)
Susitna River - mainstem						
(Sunshine fish wheels)	460	16.1	64.3	3.0	13.0	3.5
		(1.7)	(2.2)	(0.8)	(1.6)	(0.2)
Combined	843	14.1	60.5	5.1	13.4	6.9

[a] SE in parenthesis.

[b] Units = number of sockeye salmon.

also significant (P = 0.01). Therefore, a partially stratified estimator by bank was used to estimate abundance on the Susitna River system above Sunshine. The P-value for the SPAS generated goodness-of-fit test for the partially-stratified model was 0.69.

The travel rate of radiotagged fish between the tagging site and the first tracking station on the Susitna River system above Sunshine and the rate between subsequent upstream tracking stations was compared; increased travel rates in the upstream sections are consistent with a tagging-induced sulking effect (condition *b*). The median movement rates for fish radiotagged on the east bank (rkm 122.1) and subsequently detected upstream of both the Sunshine (rkm 128.3) and Talkeetna stations (rkm 156.6) were examined. The median travel rate was 15.5 km/d from the tagging site to the Sunshine station and was significantly smaller than the rate between the Sunshine and Talkeetna stations (24.6 km/d; Wilcoxon Signed Rank test; P <0.001, n = 107 fish, Table 5). The corresponding median travel rates for the west bank were 16.9 km/d and 22.2 km/d; the rate from the tagging site to the Sunshine station being marginally significantly smaller than that from the Sunshine station to the Talkeetna station (P = 0.06, n = 5 fish). Stratification of the Susitna River system above Sunshine abundance estimate by time was not used because of: (a) the potential effects of tagging on travel rates (time stratification requires untagged and tagged fish to migrate at the same rate), (b) the experiment was designed to self weight with respect to probability of capture over time, within a bank, (c) the Larson tracking station malfunctioned during 18-29 July, during which 73% of the run was counted (radio tags entering during this period were ultimately detected using aerial surveys).

The partially stratified abundance estimate for sockeye salmon in the Susitna River system above Sunshine is 70,552 fish (SE = 4,934). The overall SPAS-generated test of model fit (G^2) was not significant (P = 0.69). Bank specific abundance estimates are 62,361 fish (SE = 6,378) for the east bank and 8,190 fish (SE = 5,334) for the west bank. The probabilities of marking on the east and west banks were estimated as 0.25% and 0.95%, respectively. Only a portion of caught fish was marked and the probabilities of capture by the east and west bank fish wheels were estimated as 4.4% and 5.7%, respectively. The completely pooled Petersen estimate, by comparison, is 81,903 fish (SE = 4,967).

Table 5.-Migration rates of radiotagged Susitna River sockeye salmon between tagging site and upstream tracking stations, 2008.

Location	Bank origin	Upstream migration From	To	Distance (km)	Median speed (km/d)	Number of tags	*P*-value[a]
Susitna River system above Sunshine	East	Sunshine fish wheel	Sunshine Station	6.15	15.5	107	<0.001
	East	Sunshine Station	Talkeetna Station	28.31	24.6	107	
	East	Sunshine fish wheel	Sunshine Station	6.15	14.4	7	0.110
	East	Sunshine Station	Upper Susitna Station	36.66	12.6	7	
	East	Sunshine fish wheel	Sunshine Station	6.15	7.9	14	0.620
	East	Sunshine Station	Chulitna Station	42.38	8.9	14	
	West	Sunshine fish wheel	Sunshine Station	8.34	16.9	5	0.063
	West	Sunshine Station	Talkeetna Station	42.38	22.2	5	
	West	Sunshine fish wheel	Sunshine Station	8.34	7.1	62	0.058
	West	Sunshine Station	Chulitna Station	42.38	9.2	62	
Yentna River system	North	Yentna fish wheel	Lower Yentna Station	3.81	5.2	30	<0.001
	North	Lower Yentna Station	Chelatna Station	126.87	14.5	30	
	North	Yentna fish wheel	Lower Yentna Station	3.81	5.0	21	<0.001
	North	Lower Yentna Station	Skwentna Station	80.44	15.6	21	
	North	Yentna fish wheel	Lower Yentna Station	3.81	4.2	9	0.010
	North	Lower Yentna Station	Talachulitna Station	86.83	12.1	9	
	North	Yentna fish wheel	Lower Yentna Station	3.81	2.1	8	0.004
	North	Lower Yentna Station	Kichatna Station	89.22	7.1	8	
	North	Yentna fish wheel	Lower Yentna Station	3.81	2.2	16	0.022
	North	Lower Yentna Station	Upper Yentna Station	97.96	5.2	16	
	South	Yentna fish wheel	Lower Yentna Station	5.27	6.1	52	<0.001
	South	Lower Yentna Station	Chelatna Station	126.87	14.7	52	
	South	Yentna fish wheel	Lower Yentna Station	5.27	5.3	156	<0.001
	South	Lower Yentna Station	Skwentna Station	80.44	16.2	156	
	South	Yentna fish wheel	Lower Yentna Station	5.27	4.4	86	<0.001
	South	Lower Yentna Station	Talachulitna Station	86.83	16.3	86	
	South	Yentna fish wheel	Lower Yentna Station	5.27	3.5	17	0.220
	South	Lower Yentna Station	Kichatna Station	89.22	6.5	17	
	South	Yentna fish wheel	Lower Yentna Station	5.27	2.5	22	0.009
	South	Lower Yentna Station	Upper Yentna Station	97.96	6.0	22	

[a] Test of null hypothesis: median travel rate from fish wheel to first station is ≥ rate from first station to subsequent station, with alternative as median travel rate from fish wheel to first station is < rate from first station to subsequent station.

ESTIMATION OF ABUNDANCE-YENTNA RIVER SYSTEM

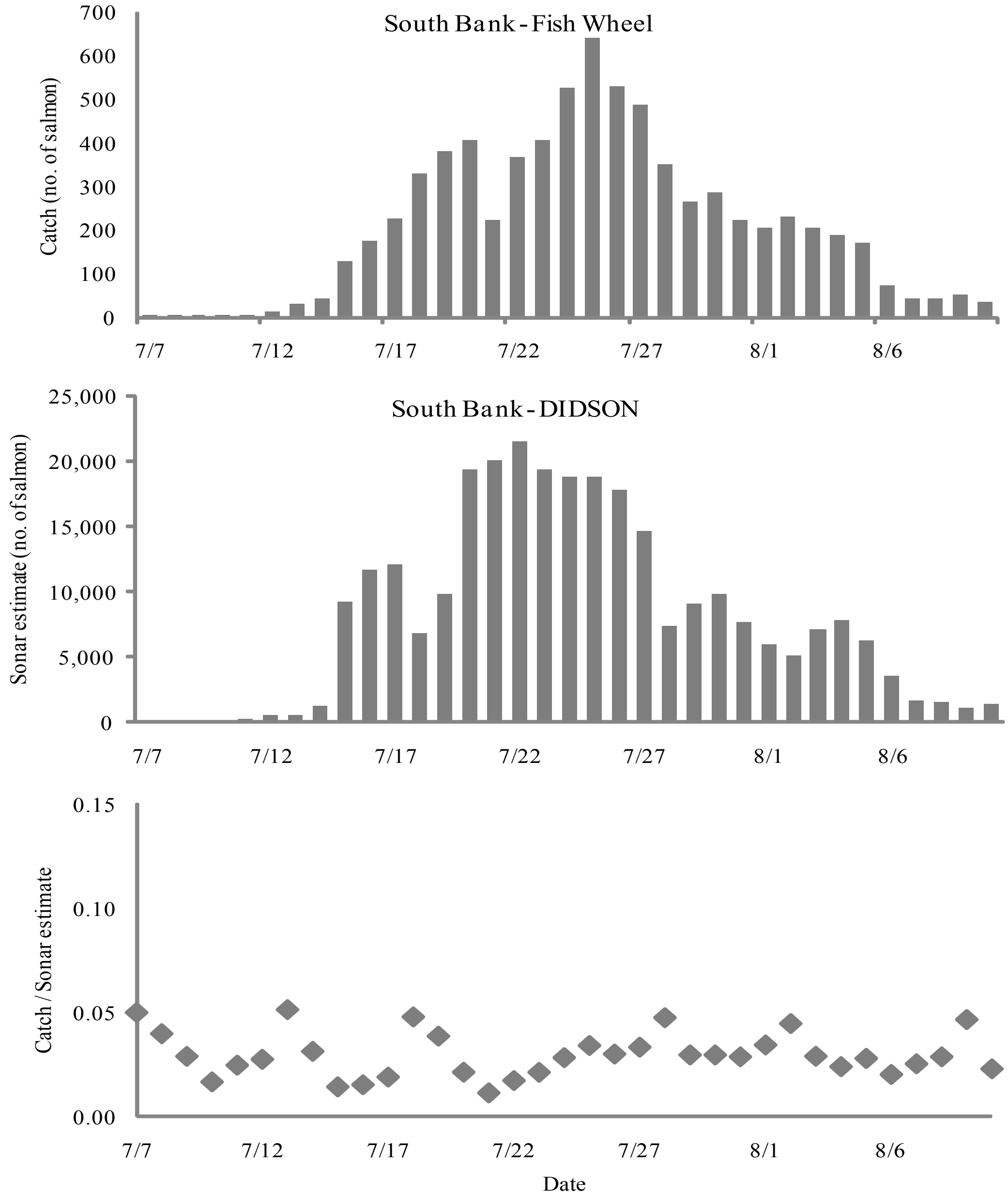
Stratification of the Yentna River abundance estimate by size was not necessary. Length distributions of fish from weir samples versus recaptured fish were not significantly different ($P = 0.065$), suggesting probability of capture during marking was not different among different size groups. Length distributions from marked fish versus recaptured fish were also not significantly different ($P = 0.35$), suggesting probability of capture in the recapture event was not different among different size groups, i.e., that the passage through the weirs was representative of the population by size. There was no difference in the length distributions of fish radiotagged by bank ($P = 0.12$); mean lengths of radiotagged fish on the north and south banks at Yentna were 536 mm (SE = 6) and 546 mm (SE = 2.5), respectively. Bank-specific lengths of untagged fish were not recorded in 2008. An estimated 55.9% (SE = 2.5%) of the sampled, untagged sockeye salmon at Yentna were age-1.3 and 11.7% (SE = 1.6%) were age-1.2 (Table 4). As a result of these tests, the Yentna River abundance estimate was not stratified by size.

The "Mixing Test," which tests for equality of recaptured:not-recaptured ratios over tagging strata (banks) was not significant ($P = 0.35$). The "Equal Proportions" test, which tests the hypothesis of equal marked:unmarked ratios over recovery sites (weirs) was significant ($P = <0.001$, Table 3). The P-value for the SPAS-generated goodness-of-fit test for the partially stratified model was 0.01. The non-significant mixing test suggests that the pooled Petersen estimate is an acceptable estimator of the Yentna drainage abundance. However, bank-specific abundance estimates (only provided by the partially-stratified estimate) were required for weighting of bank-specific terminal distributions. Given that the pooled Petersen and partially stratified estimates were very similar (see below) and in the name of consistency, the partially-stratified estimator was chosen for the overall Yentna abundance.

The travel rate of radiotagged fish between the tagging site and the first tracking station on the Yentna drainage and the rate between subsequent upstream stations was examined (Table 5). Increased travel rates in the upstream sections are consistent with a tagging-induced sulking effect (condition *b*). The median travel rates between the tagging site and the first tracking station (Lower Yentna) were significantly lower than the travel rates between the Lower Yentna station and subsequent upstream tracking stations for all 10 comparisons (Table 5, Wilcoxon Signed Rank tests).

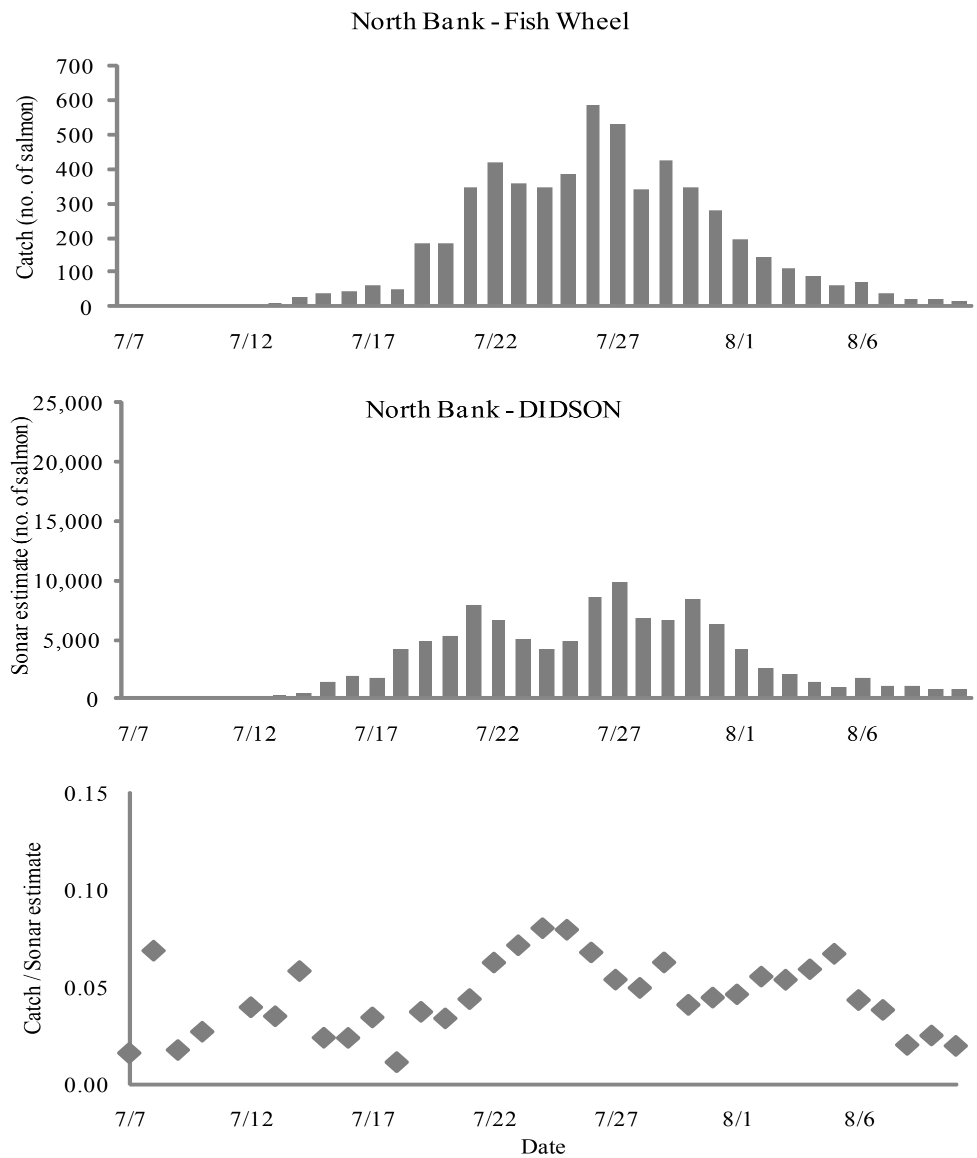
Very few radio tags (9) were censored from the Yentna experiment, showing conditions *c* and *d* were largely met at Yentna. The ratio of fish wheel catch (all species) to the DIDSON sonar total count was also examined as a way to evaluate whether tags were applied in proportion to abundance over time (Figures 3-4). No trend in capture probability was detected for the south bank. Some evidence of increased capture probability for the north bank was found, beginning approximately 20 July, followed by a slow decline in capture probability thereafter. The effect was not major and the gradual decline in capture probability was not easily modeled within the confines of the abundance estimator. No temporal stratification of the Yentna abundance estimate was conducted.

The partially-stratified estimate of abundance of sockeye salmon for the Yentna River, with banks as tagging strata and weirs as recovery strata, is 288,988 (SE = 19,159). For comparison, a pooled Petersen estimate is 281,978 (SE = 16,283). Bank-specific abundance estimates derived from the partially stratified analysis are 118,146 (SE = 3,424) and 170,842 (SE=28,863) for the



Note: The units (no. of salmon) for the south bank fish wheel catch and the south bank DIDSON sonar estimate both include "all salmon species."

Figure 3.-Fish wheel catches, DIDSON sonar estimates, and catch:sonar estimate ratio for all salmon species at Yentna River south bank, 2008.



Note: The units (no. of salmon) for the north bank fish wheel catch and the north bank DIDSON sonar estimate both include "all salmon species."

Figure 4.-Fish wheel catch, DIDSON sonar estimate, and catch:sonar estimate ratio for all salmon species at Yentna River north bank, 2008.

north and south banks, respectively. Bank-specific estimates were used as weights for the spawning distribution data (see below).

SPAWNING DISTRIBUTION AND MIGRATION TIMING

Spawning Distribution-Unweighted

Of the 607 sockeye salmon radiotagged at the Yentna (354) and Sunshine (253) fish wheels, all were detected by either tracking stations or aerial survey. Tracking stations detected 600 and aerial surveys detected 571 sockeye salmon tags. Of the 607 radiotagged sockeye salmon, 26 were assessed as having been injured by the tagging process. Of the remaining 581 radiotagged sockeye salmon, 560 (96.4%) could be assigned to a probable spawning location by either (or both) tracking station or aerial survey data.

There were 253 sockeye salmon radiotagged at Sunshine, of which 236 were deemed to have been unaffected by tagging (Table 3). Of these 236 tags, 78 originated from the west bank and 158 from the east bank. Seventy six (76) of the 78 west bank sockeye salmon were recorded at the following probable spawning locations: 5 in the Talkeetna River drainage, 21 in the Tokositna River drainage, and 50 in the Chulitna River mainstem or remaining Chulitna River tributaries (Table 6). Of the 158 fish radiotagged at the Sunshine east bank (Table 3), 148 were tracked to locations including 122 in the Talkeetna River drainage, 3 in the Susitna River system above Sunshine, 6 in the Tokositna River drainage, and 17 in the Chulitna River mainstem or remaining Chulitna River tributaries.

There were 354 sockeye salmon radiotagged at Yentna, of which 345 were deemed to have been unaffected by tagging (Table 3). Of these 345 tags, 84 originated from the north bank and 261 from the south bank. Eighty one (81) of the 84 fish tagged on the north bank that were not censored were recorded as having reached a probable spawning location: 9 tags in the Talachulitna River drainage, 12 tags in the Skwentna River mainstem or remaining Skwentna River tributaries, 32 tags in the Lake Creek drainage, 6 tags in the Kichatna River drainage, 3 tags in the Kahiltna River drainage, 18 tags in the Yentna River mainstem or remaining Yentna River tributaries, and 1 tag in the Chulitna River drainage (Table 6). For the south bank, 255 of the 261 tagged fish that were not censored were in the following probable spawning locations: 84 tags in the Talachulitna River drainage, 70 tags in the Skwentna River mainstem or remaining Skwentna River tributaries, 55 tags in the Lake Creek drainage, 14 tags in the Kichatna River drainage, 1 tag in the Kahiltna River, and 31 tags in the Yentna River mainstem or remaining Yentna River tributaries.

Twenty one (21) of the 581 radiotagged sockeye salmon that were not removed in the study due to tagging injury were not assigned to a probable spawning location. Of these 21 fish, 9 were tagged at Yentna and 12 at Sunshine:

1. For the 9 Yentna fish, 3 were of north bank origin, and were determined to be in-transit at the conclusion of the study. Six (6) of the 9 fish were of south bank origin and were determined to be in-transit.
2. For the 12 Sunshine fish, 10 were of east bank origin, and were determined to be in-transit at the conclusion of the study. Two (2) of the 12 fish were of west bank origin and were determined to be in-transit.

Table 6.-Unweighted terminal distribution of radiotagged sockeye salmon in Susitna River drainage by river system and by bank tagged, 2008.

		Tagging site					
		Yentna		Sunshine		Total	
System	Location	North bank fish wheel	South bank fish wheel	West bank fish wheel	East bank fish wheel	Number of fish	Percent
Yentna River [a]	Yentna River mainstem	18	30	0	0	48	8.6
	Lake Creek	2	3	0	0	5	0.9
	Chelatna Lake	30	52	0	0	82	14.6
	Hewitt Lake	0	1	0	0	1	0.2
	Kahiltna River	3	1	0	0	4	0.7
	Skwentna River [b]	12	60	0	0	72	12.9
	Shell Lake	0	10	0	0	10	1.8
	Talachulitna River [c]	4	17	0	0	21	3.8
	Movie Lake	0	2	0	0	2	0.4
	Trinity Lake	0	3	0	0	3	0.5
	Judd Lake	5	62	0	0	67	12.0
	Kichatna River	6	14	0	0	20	3.6
Susitna River above Sunshine	Susitna River mainstem	0	0	0	3	3	0.5
	Talkeetna River [d]	0	0	1	23	24	4.3
	Larson Lake	0	0	4	85	89	15.9
	Stephan Lake	0	0	0	14	14	2.5
	Chulitna River [e]	0	0	28	9	37	6.6
	Tokositna River	0	0	20	6	26	4.6
	Swan Lake	1	0	16	6	23	4.1
	Bunco Lake	0	0	1	0	1	0.2
	Byers Lake	0	0	6	2	8	1.4
Total		81	255	76	148	560	100.0

Note: Does not include 52 sockeye salmon not assigned to a terminal location.

[a] Yentna River (includes East and West Fork and mainstem).

[b] Skwentna River (includes Happy River, Hayes River, Moose Creek, Shell Creek, Trimble River, and upper Skwentna River).

[c] Talachulitna River (includes Talachulitna Creek).

[d] Talkeetna River (includes Iron Creek, Larson Creek, Prairie Creek, and Sheep River).

[e] Chulitna River (includes Byers Creek and Spink Creek).

No sockeye salmon tagged at Sunshine had a final spawning location in the Yentna River system and only one fish tagged at Yentna had a final spawning location in the Susitna River system above Sunshine (Swan Lake).

Of the 84 uncensored fish tagged at the Yentna north bank fish wheel, 35 (42%) were recorded passing weirs into lakes: 30 into Chelatna Lake, 5 into Judd Lake, and 0 into Shell Lake. Of the 261 uncensored fish tagged at the south fish wheel, 124 (48%) fish were recorded passing into lakes: 62 into Judd Lake, 52 into Chelatna Lake, and 10 into Shell Lake (Table 3).

Of the 78 uncensored fish tagged at the Sunshine west bank fish wheel, 20 (26%) were recorded passing weirs into lakes: 16 tags into Swan Lake, and 4 into Larson Lake. Of the 158 uncensored fish tagged at the Sunshine east bank fish wheel, 105 (67%) fish were recorded passing into lakes: 85 into Larson Lake, 14 into Stephan Lake, and 6 into Swan Lake.

Aerial surveys were conducted over the Susitna River system above Sunshine on 4 August, 12 August, 19 August, 29 September, and 10 October 2008, and over the Yentna River system on 11 August, 18 August, 26 August, 30 September, and 29 October 2008. These surveys recorded 571 different radiotagged sockeye salmon. All fish locations were corroborated by available tracking station records.

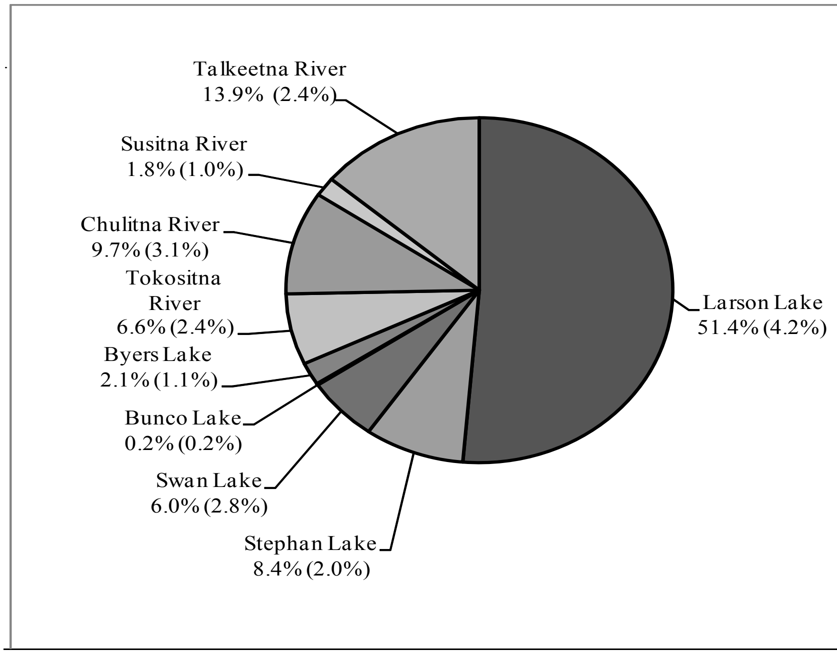
Of the 36 sockeye salmon (607-571) that were not recorded by the aerial surveys, 14 were tagged at Sunshine and 22 at Yentna. For the Sunshine fish, 3 were recorded going into Larson Lake by the weir tracking station, 3 were located in Susitna River, 4 in Larson Creek, 3 in the Chulitna River and 1 in Talkeetna River. For the Yentna fish, 2 were located in Judd Lake by the weir tracking station, 2 in the Kichatna River, 7 in the Yentna River, and 11 in the upper Skwentna River.

About 46% of the unweighted distribution of radio tags for which a probable spawning location was determined were in rivers or sloughs in 2008. For the Yentna River system, 55% and 49% of radiotagged fish were assigned spawning locations in rivers or sloughs for the north and south banks, respectively. For the Susitna River system above Sunshine, 28% and 64% of radiotagged fish were assigned spawning locations in rivers or sloughs for the east and west banks, respectively.

The unweighted terminal distribution also indicated that sockeye salmon were strongly bank oriented at the tagging sites (Table 6). For example, about 60% of the tags released from the south bank at Yentna that could be assigned a spawning location were in the Skwentna or Talachulitna river drainages, major tributaries on the south side of the Yentna River system. In comparison, only 26% of the tags from the north bank were assigned to these tributaries. Likewise, about 82% of the tags released from the east bank at Sunshine that could be assigned a final spawning location were in the Talkeetna River drainage, a major tributary on the east side of the Susitna River system above Sunshine. In comparison, only 7% of the tags from the west bank were assigned to this tributary.

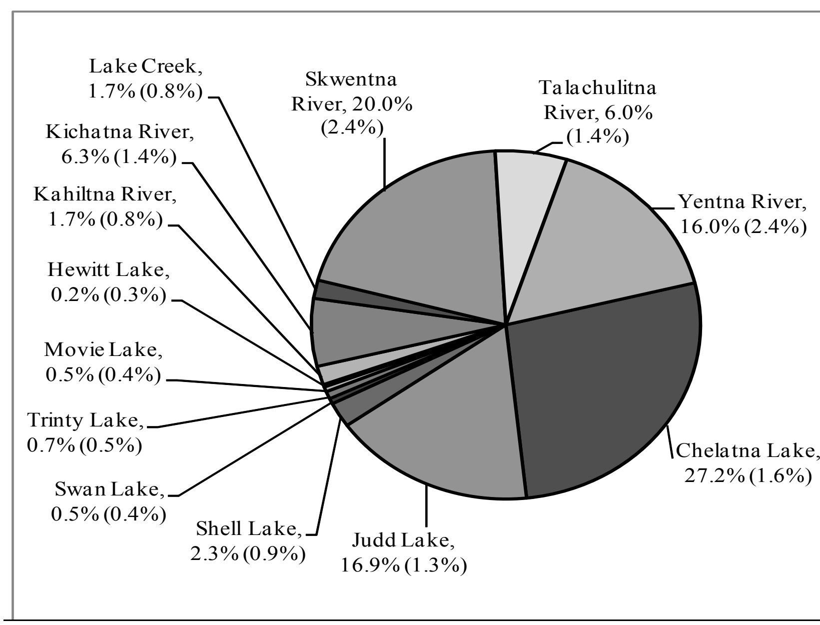
Spawning Distribution-Weighted

The heterogeneous marked:unmarked ratios for sockeye salmon observed among all the weirs indicates that the radiotag distributions within the Yentna River system and Susitna River system above Sunshine require weighting to generate unbiased estimates of the true spawner distribution. For the Susitna River system above Sunshine, the abundance-weighted distribution showed 51% (SE = 4.2%) of the spawners entered Larson Lake, and 32% were in rivers or sloughs (Figure 5). For the Yentna River system, the abundance-weighted distribution showed 27% (SE = 1.6%) of the spawners entered Chelatna Lake, 17% (SE = 1.3%) entered Judd Lake, 2% (SE = 0.9%) entered Shell Lake, and 52% were in rivers or sloughs (Figure 6). For the entire Susitna River drainage, 48% (SE = 2.6%) of the sockeye salmon escapement appeared to spawn in rivers or sloughs in 2008. Also for the entire Susitna River drainage, 45% (SE = 2.5%) of the sockeye salmon escapement in 2008 entered just the lakes with a SEG: Larson, Chelatna, and Judd lakes.



Note: SE in parenthesis.

Figure 5.-Weighted terminal distribution of sockeye salmon in the Susitna River system above Sunshine, 2008.



Note: SE in parenthesis.

Figure 6.-Weighted terminal distribution of sockeye salmon in the Yentna River system, 2008.

Migration Timing

Most sockeye salmon passing by tagging sites exhibited similar run timing, although some differences by stock were observed. Migration (run) timing was calculated only for major spawning locations, those with more than 10 radio tags.

At the Sunshine tagging site, radiotagged sockeye salmon from major spawning locations in the Susitna River system above Sunshine peaked during the week of 20–26 July (Figure 7). The median run-timing at Sunshine ranged from 24–26 July for all major spawning locations in the Susitna River system above Sunshine.

At the Yentna tagging site, radiotagged sockeye salmon from 6 major spawning locations in the Yentna River system peaked during the week of 20-26 July (Figure 8). Radiotagged sockeye salmon at 2 other major spawning locations peaked a week earlier. The median run-timing at the Yentna tagging site ranged from 19–23 July for all major spawning locations.

DISCUSSION

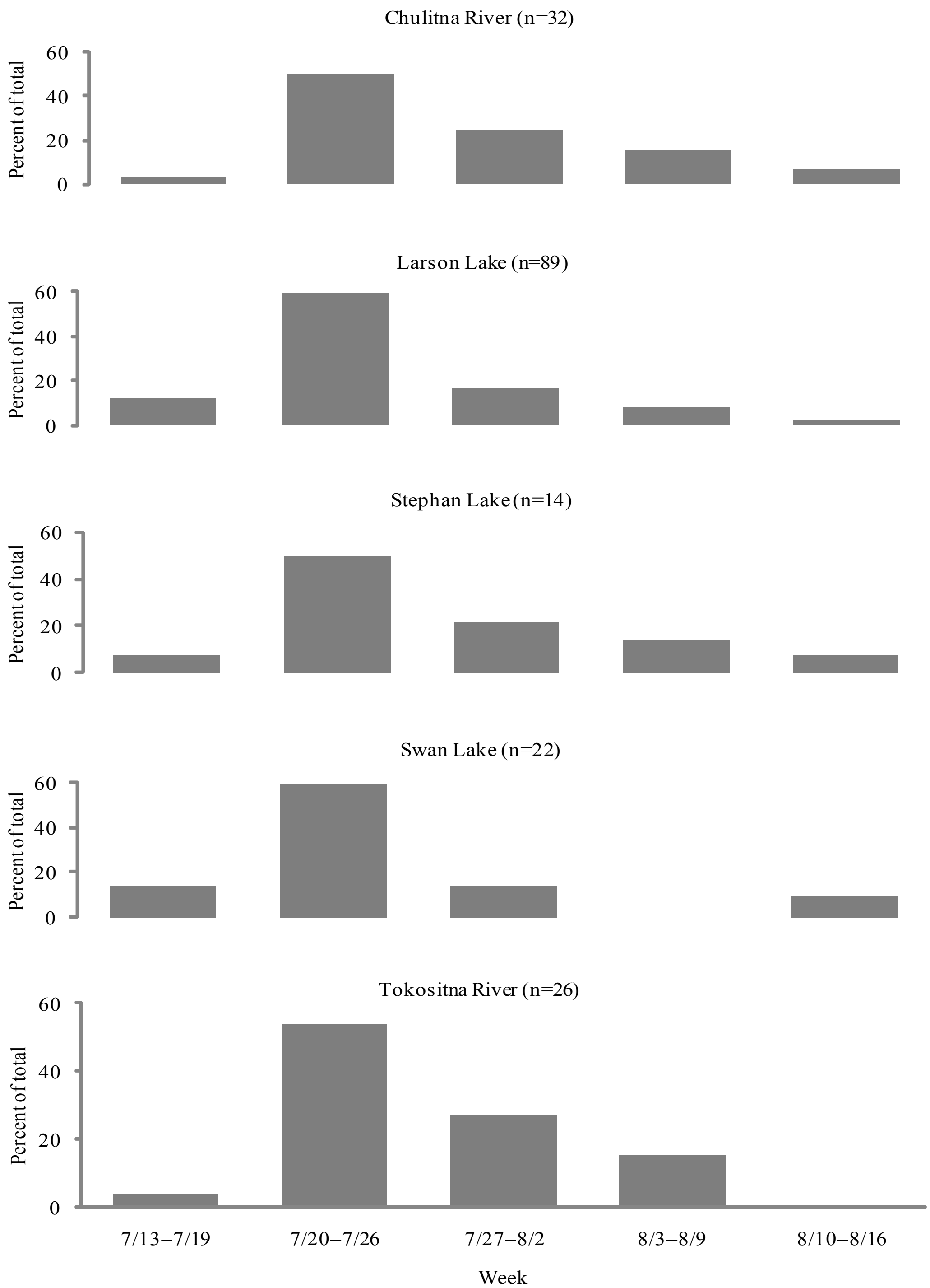
ABUNDANCE

Capture-recapture abundance estimates of the sockeye salmon escapement in the Susitna River system above Sunshine and Yentna River system were generated by design in 2008. Necessary conditions were met in the Susitna River system above Sunshine for a partially stratified estimator to produce an inriver abundance estimate of 70,552 fish (SE = 4,934), for a 95% relative precision of 14%. A partially stratified estimate was appropriate for the Yentna River system, which is 288,988 fish (SE = 19,159), for a 95% relative precision of 13%.

Combining the Susitna River system above Sunshine and Yentna River system abundance estimates generates a sockeye salmon escapement estimate of 359,540 (SE = 19,784) fish for the entire Susitna River drainage, with the Yentna River system contributing 80% (SE = 1.5%) and the Susitna River system above Sunshine contributing 20% (SE = 1.5%). Previously, the Yentna Bendix sonar-fish wheel estimate has been expanded by 1.95 to estimate the sockeye salmon escapement to the entire Susitna River drainage (Fox 1998). The expansion factor using the capture-recapture estimates in 2008 is much less, at 1.24 (359,540/288,988), and was also much less in 2007 at 1.37 (327,732/239,849), for an average expansion factor of 1.31 (Yanusz et al. *In prep*).

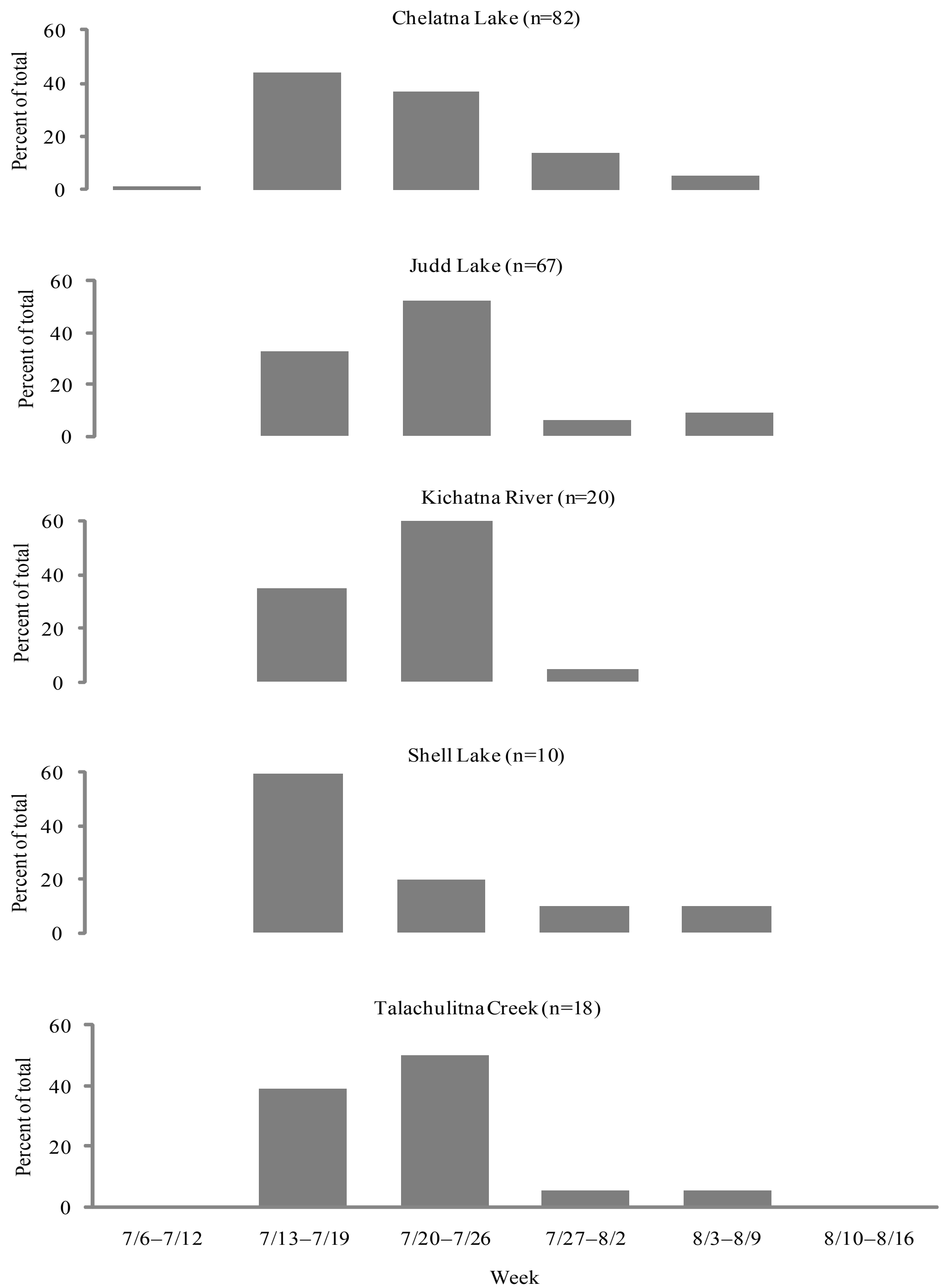
The 2008 study had two major design changes from the 2007 study that were successful. The first change was construction of a floating weir at Chelatna Lake that ensured a complete count was obtained in 2008; failure of the fixed picket weir at Chelatna Lake in 2007 for part of the season because of high flows compromised the capture-recapture data. The second change was an intentional variation in the tagging rate used on the east and west banks at Sunshine. This change ensured much better estimates of the spawning distribution of the west-bank oriented population in 2008; in 2007 only 23 tags were applied on the west bank while in 2008, 78 tags were applied. Only one sockeye salmon switched river systems in 2008 (four did so in 2007; Yanusz et al. *In prep*), giving a very strong indication that the two river systems are separate populations, and the 2-experiment design is appropriate (condition *d*).

Application of differential tagging rates by bank for the Susitna River system above Sunshine suggested that the data analysis would require stratification of the tagging event by bank; diagnostic tests confirmed this and a partially–stratified estimator was used. As for 2007, tag



Note: Number in parenthesis = the number of radiotagged fish that migrated to this location.

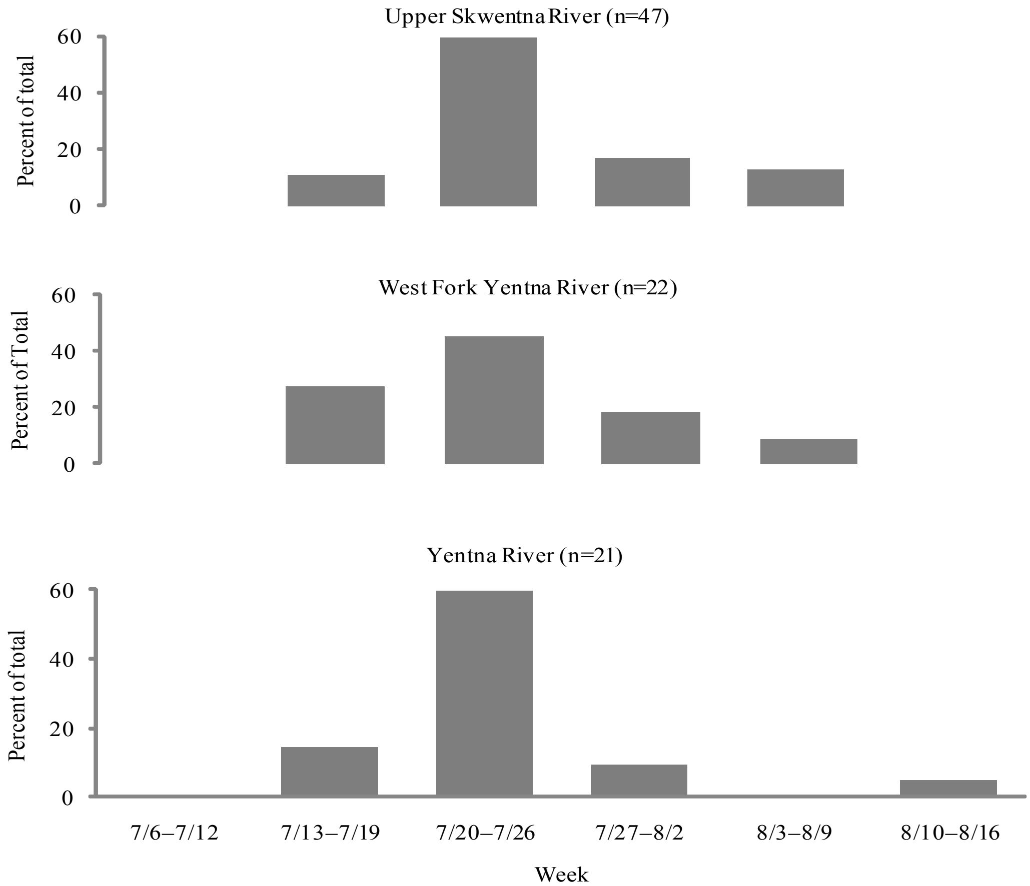
Figure 7.-Run timing (percent per week) of radiotagged sockeye salmon passing the Sunshine tagging site to terminal locations in the Susitna River system above Sunshine, 2008.



Note: Number in parenthesis = the number of radiotagged fish that migrated to this location.

Figure 8.-Run timing (percent per week) of radiotagged sockeye salmon passing the Yentna tagging site to terminal locations in the Yentna River system, 2008.

-continued-



Note: Number in parenthesis = the number of radiotagged fish that migrated to this location.

Figure 8.–Page 2 of 2.

detection and tag loss was not an issue because only radio tags were used, and by design all were tracked. Any substantial tag detection or loss problems would have been obvious and quantifiable (condition *c*). In 2006, it appeared there were likely non-lethal effects of radio tagging on behavior (condition *b*), since radiotagged fish were slower to reach their destination than PIT tagged fish (Yanusz et al. 2007). Handling time was reduced in 2007 by tagging fish as they were caught, instead of allowing fish to collect in the live box of a fish wheel. No conclusive evidence was gained from comparisons of travel rates immediately after tagging to subsequent travel rates in 2007. In 2008, the evidence was stronger for increased travel rates in the river sections further upstream, especially for the Yentna River. The 2008 abundance estimates do not include an adjustment for travel rate of tagged fish because the weirs were operated for the duration of the 2008 run and no temporal stratification of the tagging strata was used. If any sub-lethal effects prevented radiotagged fish from passing through the weirs, the abundance estimates would be biased high.

Ideally, the sonar-fish wheel and capture-recapture estimates of the sockeye salmon abundance should be similar. However, the Bendix sonar-fish wheel estimate of the sockeye salmon abundance passing Yentna in 2008 was 90,146 fish (Westerman and Willette 2010) and the DIDSON sonar-fish wheel estimate was 131,772 fish (Fair et al. 2009), which are significantly lower than the capture-recapture abundance estimate for the Yentna River system. The Bendix sonar-fish wheel estimate is even less than the sum of the three weir counts in the Yentna River system (130,394, Table 7), and the DIDSON sonar-fish wheel estimate is only about 1,400 fish greater than the sum of the weir counts. The three weirs accounted for an estimated 46% of the Yentna River system spawner distribution, implying both sonar-fish wheel estimates should have greatly exceeded the sum of the weir counts.

Some of the discrepancies could be due to overestimating the abundance with the capture-recapture experiment or underestimating the spawner distribution in Chelatna, Shell, and Judd lakes. But proportional tagging, accounting for every tag, large sample sizes, full-season weir counts, the results of the diagnostic tests, and weighting the spawner distributions all give robustness to the capture-recapture data in 2008. If the species apportionment using the fish wheel catches was not representative of the true species composition in the river, it may explain some of the sonar-fish wheel abundance discrepancy. The abundance estimates for other species at Yentna were high enough to substantially affect sockeye salmon abundance estimates if non-representative sampling occurred. Based on apportioned Bendix sonar-fish wheel counts, there were an estimated 115,512 pink salmon, 10,212 chum salmon, and 33,784 coho salmon at Yentna in 2008 (Westerman and Willette 2010). A similar pattern of discrepancies among the three assessment methods was found in 2006 and 2007 (Yanusz et al. 2007, Yanusz et al. *In prep*).

SPAWNING DISTRIBUTION AND MIGRATION TIMING

An unbiased terminal distribution of the sockeye salmon escapement in the entire Susitna River drainage was possible for the first time in 2008 due to the successful, by-bank, abundance estimates. The weighted estimate of the escapement to the three lakes with an SEG (Larson, Chelatna, and Judd lakes) using radiotelemetry data was 45% (SE = 2.5%). Based on unweighted radiotag distributions, the three lakes received an estimated 46% to 58% of the annual sockeye salmon escapement between 2006 and 2008 (Yanusz et al. 2007, Yanusz et al. *In prep*).

Within the Susitna River system above Sunshine, Larson Lake received an estimated 51% (weighted) of the escapement in 2008 and 55% (weighted) in 2007 (Yanusz et al. *In prep*). Next most abundant in the Susitna River system above Sunshine were apparent river and slough spawners, making up an estimated 29% (weighted) to 32% (weighted) of the escapement in 2007 and 2008. Visual inspection of the terminal distribution maps shows most of the river and slough spawners were located in the Chulitna and Tokositna rivers in 2007 and 2008.

Sockeye production is more dispersed in the Yentna River system. Within the Yentna River system, 48% (weighted, SE = 2.9%) of sockeye salmon appeared to enter lakes to spawn in 2008. Chelatna Lake was the principle Yentna sockeye stock in 2008, followed by the Skwentna River, Judd Lake, and the mainstem, side channels, or sloughs of Yentna River. The lack of a complete weir count at Chelatna Lake and qualified abundance estimates in 2006 and 2007 precludes direct comparisons of the spawner distributions with 2008, but the unweighted radiotag distributions in 2006 and 2007 suggest the four stocks above are annually the principle sockeye

Table 7.-Comparison of sockeye salmon escapement estimates in Susitna River drainage, 2008.

		Abundance estimate		
Population estimated	Method	Point	Lower 95% CI	Upper 95% CI
Yentna River system	Pooled Petersen capture-recapture	281,978	250,061	313,894
Yentna River system	Partially stratified capture-recapture	288,988	251,436	326,540
Yentna River system	Bendix sonar-fish wheel	90,146 [a]		
Yentna River system	DIDSON sonar-fish wheel	131,772 [a]		
Yentna River system - lakes with weirs [b]	Weir	130,394 [c]		
Susitna River system above Sunshine	Partially stratified capture-recapture	70,552	60,882	80,221
Susitna River system above Sunshine - lakes with weirs [d]	Weir	43,543 [c]		

[a] Source: Fair et al. (2009).

[b] Yentna River system sockeye salmon were counted at weirs on Judd, Shell, and Chelatna lakes.

[c] Source: CIAA (Cook Inlet Aquaculture Association). 2008. Sockeyes salmon escapement data from weirs operated at the outlet of select lakes by CIAA. http://www.ciaanet.org/content_sub.asp?SUB_ID=14&CAT_ID=6 (Accessed 1 November 2008, site updated annually with current year data only). Soldotna, AK.

[d] Weirs located on the Susitna River system above Sunshine were operated at Swan, Stephan, and Larson lakes.

salmon stocks in the Yentna River system, in varying order each year (Yanusz et al. 2007, Yanusz et al. *In prep*). Shell Lake sockeye salmon escapements are highly variable, in 2006 it had the largest escapement (69,800 fish). The apparent river and slough spawners, while most abundant in the Skwentna, Yentna, and Kichatna rivers, were well dispersed within each river in 2007 and 2008. The apparent river and slough spawners were not as dispersed in 2006, but that may be because fewer radio tags were deployed that year and fewer sites were detected.

The 2008 peak run timing for all sockeye salmon stocks was similar to 2006 run timing (Yanusz et al. 2007). The 2007 peak run timing was 1 week later for most stocks, and sometimes 2 weeks later (e.g., Chulitna, Stephan, Chelatna, Yentna), than the 2008 peak run times (Yanusz et al. *In prep*).

ACKNOWLEDGMENTS

We thank the Commissioner of ADF&G Denby Lloyd for his support. C. Swanton, R. Clark, J. Hasbrouck, and J. Erickson from the Sport Fish Division (SFD) in Anchorage and J. Hilsinger, J. Regnart, and L. Fair from Division of Commercial Fisheries (CFD) in Anchorage provided advice and project oversight. From CFD in Soldotna, D. Westerman supervised the Yentna camp, K. Rudge-Karic conducted field logistics and data entry, and T. Tobias read the scale ages. From SFD in Palmer D. Rutz, A. Oels, C. Brockman, S. Ivey, and D. Miller provided logistical support, J. Cross and R. Driscoll of CFD assisted with the radio tracking and data tabulation. J. Berger from the ADF&G Gene Conservation Laboratory provided instructions and supplies for collecting tissue samples.

J. Bullock and N. Logelin from SFD in Palmer provided field supervision and logistical support for Sunshine and downloaded all remote radio receivers. L. Vail (crew leader) and C. McBride of SFD performed the fish wheel sampling at Sunshine. D. Reeves, E. Snyder, M. Villegas, and T. Hrebar built and assisted with onsite placement of the Chelatna Lake weir. T. D. Hacken (crew leader), S. Walker (crew leader), K. Dent, and R. Maryott from CFD performed the sampling at the Yentna River camp.

G. Frandrei, P. Blanche, D. Frisbee, and R. Carlson from Cook Inlet Aquaculture Association (CIAA) provided funding, design, logistics, and supervision for the weirs. CIAA field crews were Z. Hill and P. Hill at Chelatna Lake weir; K. Waite and B. Lamb at Swan Lake weir; E. Davies and Z. Kilm at Judd Lake weir; P. Shumaker, F. Ward, and S. Fickel at Larson Lake weir; R. Swift and S. Philibosian at Shell Lake weir; and J. Brown and M. Yakich at Stephan Lake weir. Technical assistance with radiotelemetry was provided by N. Christensen, L. Kuechle, A. Mayer, and R. Reichle of Advanced Telemetry Systems, Inc. (ATS). Also, thank you for the support and understanding of the Matanuska-Susitna Advisory Committee.

The following businesses and people greatly assisted with the logistics of the field operations: the Talachulitna Lodge, Chelatna Lake Lodge, Last Frontier Aviation, Arctic Wings, Willow Air (Service), Rust’s Flying Service, Forks Roadhouse, B. Bryant, C. Norvell, J. Norvell, K. Coleman, and S. Coleman.

This project was funded by a Capital Improvement Project from the Alaska State Legislature, the State of Alaska operating budget, and the Wildlife and Sport Fish Restoration program.

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APPENDIX A

Appendix A1.-Total daily salmon catch, radio tags applied, and effort for both fish wheels combined at Sunshine, 2008.

	Catch (no. of fish)					Radiotagged sockeye salmon	Total combined fish wheel effort
Date (m/dd)	Chinook salmon	Coho salmon	Pink salmon	Chum salmon	Sockeye salmon	(no. of fish)	(h)
7/05	20	0	0	0	4	0	12.8
7/06	16	0	0	1	3	0	12.1
7/07	12	0	0	0	1	0	13.1
7/08	2	0	0	0	0	0	12.2
7/09	2	0	0	0	0	0	12.2
7/10	4	0	2	0	0	0	12.0
7/11	6	0	2	0	1	0	12.4
7/12	4	0	0	0	2	0	12.0
7/13	4	0	2	0	2	0	12.3
7/14	3	0	0	0	2	0	12.0
7/15	1	0	3	0	11	1	12.3
7/16	2	0	2	0	8	0	12.5
7/17	1	0	2	0	30	2	12.0
7/18	1	0	5	1	150	11	12.4
7/19	1	0	1	2	164	11	12.5
7/20	0	0	3	0	196	18	12.0
7/21	3	0	7	5	170	13	12.0
7/22	5	0	7	2	260	19	12.4
7/23	1	0	19	5	312	22	12.0
7/24	1	0	28	9	274	21	12.0
7/25	0	1	54	15	257	21	12.0
7/26	1	0	160	34	327	31	12.3
7/27	0	3	249	109	286	16	12.0
7/28	1	11	395	110	194	14	12.0
7/29	0	21	208	42	82	8	12.0
7/30	1	16	84	20	17	1	9.3
7/31	1	13	96	8	24	2	12.0
8/01	0	86	235	34	50	5	12.4
8/02	0	78	629	32	26	2	12.4
8/03	0	121	489	66	32	2	6.0
8/04	0	138	311	50	32	2	6.0
8/05	1	282	288	72	50	5	12.5
8/06	0	205	189	43	27	3	12.1
8/07	0	296	309	96	53	5	12.6
8/08	0	347	317	111	52	6	12.1
8/09	0	413	186	160	36	3	12.3
8/10	0	349	100	184	23	3	12.0
8/11	0	476	83	231	24	3	12.5
8/12	0	276	72	153	19	3	12.2
Total	94	3,132	4,537	1,595	3,201	253	461.8

Appendix A2.-Total daily salmon catch, radio tags applied, and effort for both fish wheels combined at Yentna, 2008.

Date (m/dd)	Catch (no. of fish) Chinook salmon	Coho salmon	Pink salmon	Chum salmon	Sockeye salmon	Radiotagged sockeye salmon (no. of fish)	Total combined fish wheel effort (h)
7/07	2	0	0	0	1	0	12.0
7/08	1	0	0	0	8	0	12.0
7/09	0	1	0	0	4	1	12.0
7/10	1	0	0	0	1	0	12.0
7/11	0	0	0	0	5	0	12.0
7/12	0	7	1	0	9	1	12.0
7/13	1	14	5	1	16	2	12.0
7/14	1	23	15	4	23	1	12.3
7/15	0	43	15	2	104	11	12.0
7/16	3	41	12	2	160	14	12.2
7/17	1	65	28	1	192	18	12.0
7/18 [a]	0	22	10	2	293	32	6.0
7/19 [a]	0	28	22	1	330	33	6.0
7/20	1	60	79	5	443	45	10.0
7/21	0	64	278	24	200	30	12.2
7/22	4	120	443	16	198	22	12.0
7/23	0	99	369	13	281	27	12.0
7/24	0	89	549	17	215	23	12.0
7/25	1	109	729	12	173	17	12.0
7/26	1	83	946	8	73	6	12.0
7/27	0	92	859	19	42	6	12.0
7/28	0	72	504	40	68	7	12.0
7/29	0	70	530	5	83	8	12.1
7/30	0	91	471	24	40	4	12.0
7/31	0	53	370	18	57	5	12.0
8/01	0	45	272	33	46	5	12.0
8/02	0	63	198	46	67	7	12.1
8/03	0	55	129	60	71	6	12.1
8/04	0	45	102	50	78	10	12.1
8/05	0	27	111	41	53	5	12.2
8/06	0	23	64	37	22	1	12.2
8/07	0	15	31	19	16	2	12.2
8/08	0	12	25	14	13	1	12.2
8/09	0	7	15	18	27	2	12.0
8/10	0	8	11	10	17	2	12.2
Total	17	1,546	7,193	542	3,429	354	408.1

[a] The north bank fish wheel was inoperable on 18 and 19 July.

Appendix A3.-Daily passage of Susitna River sockeye salmon through escapement weirs, 2008.

	Susitna River system above Sunshine				Yentna River system			
Date (m/dd)	Larson Lake [a]	Stephan Lake	Swan Lake	Total	Judd Lake	Shell Lake	Chelatna Lake	Total
7/01				0				
7/02				0				
7/03				0				
7/04				0				
7/05				0				
7/06				0				
7/07	gin counts			0				
7/08	0			0				
7/09	0			0			Install	
7/10	2	Install		2			0	0
7/11	0	0		0			0	0
7/12	0	0		0			0	0
7/13	1	0	Install	1			0	0
7/14	2	0	0	2	Install		0	0
7/15	3	0	0	3	0	Install	0	0
7/16	1	1	0	2	0	0	0	0
7/17	0	1	0	1	0	0	0	0
7/18	7	0	0	7	0	0	2	2
7/19	55	2	0	57	0	0	6	6
7/20	1,108	2	0	1,110	0	0	2	2
7/21	1,535	0	0	1,535	0	0	4	4
7/22	2,407	4	0	2,411	0	0	1,133	1,133
7/23	3,811	0	0	3,811	0	0	3,390	3,390
7/24	2,118	14	0	2,132	0	0	3,329	3,329
7/25	3,543	150	0	3,693	0	0	5,737	5,737
7/26	1,826	492	0	2,318	0	1	6,187	6,188
7/27	3,810	439	0	4,249	0	0	8,933	8,933
7/28	1,960	186	0	2,146	0	2	8,531	8,533
7/29	3,093	84	5	3,182	874	5	5,113	5,992
7/30	966	170	1	1,137	1,024	1,228	7,068	9,320
7/31	393	47	111	551	7,523	15	6,412	13,950
8/01	207	55	60	322	3,823	2	4,921	8,746
8/02	641	0	76	717	4,669	16	2,119	6,804
8/03	786	125	85	996	779	1	2,008	2,788
8/04	513	393	185	1,091	730	0	1,967	2,697
8/05	873	544	147	1,564	6,483	1	1,248	7,732
8/06	585	469	220	1,274	5,107	1	1,051	6,159
8/07	601	228	209	1,038	899	2	658	1,559
8/08	246	144	299	689	6,081	0	1,119	7,200
8/09	383	235	138	756	1,880	0	729	2,609
8/10	790	153	153	1,096	2,069	2	696	2,767
8/11	614	78	128	820	811	257	366	1,434
8/12	351	149	331	831	1,596	157	47	1,800

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	Susitna River system above Sunshine				Yentna River system			
Date (m/dd)	Larson Lake [a]	Stephan Lake	Swan Lake	Total	Judd Lake	Shell Lake	Chelatna Lake	Total
8/13	226	150	107	483	1,936	0	63	1,999
8/14	180	83	145	408	1,295	37	52	1,384
8/15	70	173	124	367	436	23	42	501
8/16	471	45	215	731	899	15	26	940
8/17	154	58	141	353	325	744	17	1,086
8/18	20	40	144	204	515	0	8	523
8/19	37	145	100	282	202	0	9	211
8/20	8	29	112	149	461	2	110	573
8/21	1	26	54	81	271	0	127	398
8/22	0	20	126	146	294	20	68	382
8/23	35	29	42	106	278	29	78	385
8/24	19	5	77	101	122	16	64	202
8/25	24	6	65	95	167	0	15	182
8/26	16	5	51	72	128	8	14	150
8/27	20	1	71	92	212	0	Removed	212
8/28	4	0	21	25	163	21		184
8/29	0	0	23	23	599	1		600
8/30	Removed	6	50	56	246	5		251
8/31		2	17	19	184	0		184
9/01		0	78	78	99	0		99
9/02		0	16	16	182	6		188
9/03		2	0	2	607	7		614
9/04		Removed	18	18	259	Removed		259
9/05			33	33	46			46
9/06			59	59	27			27
9/07			Removed	0	Removed			0
9/08				0				0
9/09				0				
9/10				0				0
9/11				0				0
9/12				0				0
9/13				0				0
9/14				0				0
Total	34,516	4,990	4,037	43,543	54,301	2,624	73,469	130,394

Source: CIAA (Cook Inlet Aquaculture Association). 2008. Sockeye salmon escapement data from weirs operated at the outlet of select lakes by CIAA. http://www.ciaanet.org/content_sub.asp?SUB_ID=14&CAT_ID=6 (Accessed 1 November 2008, site updated annually with current year data only).

Note: "Install" is the date the full river picket weir was set up. "Removed" is the date the full river picket weir was taken down.

[a] The 524 sockeye salmon counted prior to 8 July were not included in the abundance estimate as the adult weir was not operational until that date.