Fishery Data Series No. 10-72

Distribution of Spawning Susitna River Chum *Oncorhynchus keta* and Coho *O. kisutch* Salmon, 2009

by

Richard A. Merizon,

Richard J. Yanusz,

Dan J. Reed,

and

Ted R. Spencer

November 2010

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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. 10-72

DISTRIBUTION OF SPAWNING SUSITNA RIVER CHUM *ONCORHYNCHUS KETA* AND COHO *O. KISUTCH* SALMON, 2009

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

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

Dan J. Reed
Alaska Department of Fish and Game, Division of Sport Fish, Nome

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

November 2010

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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

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

Dan J. Reed
Alaska Department of Fish and Game, Division of Sport Fish
103 E. Front St., Nome, AK 99762-1148 USA

and

Ted R. Spencer
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Rd, Anchorage, AK 99518-1565 USA

This document should be cited as:
Merizon, R. A., R. J. Yanusz, D. J. Reed, and T. R. Spencer. 2010. Distribution of spawning Susitna River chum Oncorhynchus keta and coho O. kisutch salmon, 2009. Alaska Department of Fish and Game, Fishery Data Series No. 10-72, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES ii
LIST OF FIGURES iii
ABSTRACT 1
INTRODUCTION 1
STUDY AREA 2
METHODS 2
Radiotag Application 2
Radiotag Relocation 3
  Tracking Stations 3
  Aerial Surveys 4
RESULTS 4
Radiotag Application 4
  Tracking Stations 4
  Aerial Surveys 5
  Spawning Location 5
DISCUSSION 6
ACKNOWLEDGMENTS 7
REFERENCES CITED 8
TABLES 11
FIGURES 21

LIST OF TABLES

Table		Page
1.	Operating dates for Susitna River fish wheels and weirs at Flathorn (rkm 35), 2009.	13
2.	Location of tracking stations used to monitor the movements of radiotagged chum and coho salmon in Susitna and Yentna River drainages, 2009.	13
3.	Total daily fish wheel effort, catch, and number of radio tags applied by species, Susitna River at Flathorn, 14 July to 30 August 2009.	14
4.	Chum and coho salmon radio tags deployed by week, 2009.	15
5.	Movement and migration pattern descriptions used to determine the final spawning location of radiotagged salmon relocated during aerial surveys in 2009.	16
6.	Regional distribution of radiotagged chum and coho salmon in the Susitna and Yentna River drainages, 2009.	17
7.	Unweighted terminal distribution (number of fish and percent) of radiotagged chum salmon in the Susitna River drainage by fish wheel, 2009.	18
8.	Unweighted terminal distribution (number of fish and percent) of radiotagged coho salmon in the Susitna River drainage by fish wheel, 2009.	19

LIST OF FIGURES

Figure **Page**

1. Location of Flathorn tagging site (circle) and fixed radiotracking stations (diamonds) in the Susitna River drainage, 2009. 23
2. Location of Flathorn fish wheels (circles), Flathorn Camp (rectangle), and radiotracking station (open circle), 2009..... 24
3. Final spawning distribution of chum salmon radiotagged at all fish wheels in 2009. 25
4. Final spawning distribution of chum salmon radiotagged at fish wheel number 1, 2009. 26
5. Final spawning distribution of chum salmon radiotagged at fish wheel number 2, 2009. 27
6. Final spawning distribution of chum salmon radiotagged at fish wheel number 3, 2009. 28
7. Final spawning distribution of chum salmon radiotagged at fish wheel number 4, 2009. 29
8. Final spawning distribution of coho salmon radiotagged at all fish wheels in 2009. 30
9. Final spawning distribution of coho salmon radiotagged at fish wheel number 1, 2009..... 31
10. Final spawning distribution of coho salmon radiotagged at fish wheel number 2, 2009..... 32
11. Final spawning distribution of coho salmon radiotagged at fish wheel number 3, 2009..... 33
12. Final spawning distribution of coho salmon radiotagged at fish wheel number 4, 2009..... 34

ABSTRACT

Because of recent concerns over the status of the Susitna River chum *Oncorhynchus keta* and coho *O. kisutch* salmon stocks, the Alaska Department of Fish and Game began a 4-year spawning distribution study in 2009. Four fish wheels were used to capture and radiotag chum and coho salmon in the lower Susitna River from July through August 2009. A total of 539 radio tags were placed in chum and coho salmon. Their movements were tracked using 13 ground tracking stations and 4 complete drainage-wide aerial surveys. All but 1 of the radio tags were relocated and 485 (90%) were assigned a final spawning location. Both chum and coho salmon exhibited bank orientation at the tagging site. Chum salmon utilized predominately mainstem locations while coho salmon utilized predominately tributary locations.

Key words: chum salmon, coho salmon, Susitna River, Yentna River, spawning distribution, fish wheel, radiotelemetry

INTRODUCTION

The Susitna River chum *Oncorhynchus keta* and coho *O. kisutch* salmon runs are unknown, but likely substantial contributors to the commercial and sport fisheries in upper Cook Inlet (UCI). The 1966–2006 average commercial harvest in UCI was 313,000 coho salmon and 478,000 chum salmon (Shields 2007). Sport harvests in Susitna River averaged 40,767 coho salmon and 2,893 chum salmon from 1998 to 2007 (Ivey et al. 2007; Jennings et al. 2010).

The distribution and abundance of spawning coho and chum salmon in the entire Susitna River drainage is not well known. However, between 1981 and 1985 (e.g., years when environmental impact studies were conducted for a proposed Susitna River hydroelectric project) the estimated abundance averaged 565,000 chum salmon and 134,000 coho salmon passing Flathorn (Susitna River kilometer (rkm) 35) using mark-recapture techniques (Barrett et al. 1984; Thompson et al. 1986). Researchers also radiotagged chum (n=29) and coho (n=26) salmon in the upper Susitna River in 1981 and 1982 that provided information on spawning locations for each species. Radiotagged chum salmon utilized sloughs within the mainstem Susitna River, clear water tributaries, and confluence zones. Radiotagged coho salmon typically utilized tributaries within the mid-Susitna River drainage and small clearwater tributaries (Barrett et al. 1984; Thompson et al. 1986). In 2002, the Susitna River estimated escapement was 358,000 coho salmon, using mark-recapture techniques (Willette et al. 2003). In the same study, 189 radiotagged coho salmon were tracked into the Susitna River drainage and provided the first drainagewide spawning distribution information for coho salmon.

Coho and chum salmon stock status in Susitna River have been issues brought before the Alaska Board of Fisheries (BOF) by user groups. The BOF issued resolution 2008-253-FB to the Alaska Legislature supporting funding for fisheries research. At the 2008 BOF meeting, there were 69 proposals to modify commercial fishing regulations in UCI and 2 proposals for sport fishing regulations in the Susitna River, demonstrating the dynamic nature of the fisheries. The Matanuska-Susitna Borough issued a resolution on 15 January 2008 requesting the Alaska Department of Fish and Game (ADF&G) to declare Susitna River chum salmon a "stock of concern," enumerate salmon escapements, and set escapement goals for all salmon in northern Cook Inlet. The Alaska State Legislature issued Legislative Resolve Number 51 in 2008 establishing the Cook Inlet Salmon Task Force to examine "conservation and allocation issues."

In 2009, ADF&G initiated a 4-year study (2009 to 2012) to capture and apply radio tags to chum and coho salmon in the lower Susitna River. Radiotagged fish were relocated using fixed

tracking stations and repeated aerial surveys (Figure 1). The objective in 2009 was to identify chum and coho salmon spawning locations throughout the Susitna River drainage.

STUDY AREA

The Susitna River drainage comprises 49,210 km^2 and originates in the Alaska Range north of Anchorage (Figure 1). It is the fourth largest drainage in the state of Alaska. It flows generally south from the Alaska Range for approximately 400 km before entering UCI west of Anchorage. The largest tributaries are the Yentna, Chulitna, and Talkeetna rivers, and there are numerous small lakes (King and Walker 1997).

The morphology of Susitna River varies by location. Rivers in the drainage originate in the Alaska or Talkeetna Mountain ranges and some are clear or glacially turbid (Sweet et al. 2003).

METHODS

RADIOTAG APPLICATION

Four fish wheels were operated in 2009 at Flathorn (rkm 35); one on each bank of two Susitna River channels (Figure 2). This site was selected because it is upstream of an area that is highly braided yet downstream of the confluence with the Yentna River. Each fish wheel had 2 × 2 m baskets that were adjusted as needed to fish ≤0.3 m from the river bottom. Picket weirs located between the fish wheel and the river bank were operated for the entire season (Table 1).

Division of Sport Fish (DSF) personnel were responsible for operating and radiotagging chum and coho salmon from fish wheels number 2, 3, and 4. Division of Commercial Fisheries (DCF) personnel conducted a separate study utilizing fish wheel number 1 between 14 July and 6 August 2009. During this period DCF crews operated the fish wheel and radiotagged chum and coho salmon according to the methods outlined in this report. Beginning 7 August, DSF was responsible for operating all 4 fish wheels through the end of field operations (30 August). DSF crews worked 2 shifts of 7.5 h each spaced 1 h apart during daylight hours, for a total of 15 h of effort per day. The DCF crews worked 2 shifts, of 9 h each spaced 1 h apart. Shift starting times were systematically rotated to sample most hours of the day over the course of the 4 days. It was assumed that there was no substantial diel variation in the stock composition of fish passage.

Fish wheels were checked at least once an hour during sampling shifts. Only uninjured chum and coho salmon ≥400 mm in length from mid eye to tail fork (METF) were radiotagged. Chum and coho salmon <400 mm METF were not radiotagged. Most coho salmon <400 mm METF were jacks (males that spent only one winter at sea) and may not have the same capture probability at the fish wheels as older fish because of their small size. To minimize handling effects, coho salmon receiving a radio tag were either: (1) taken directly out of the fish wheel basket as they were captured, or (2) taken out of the fish wheel live box if the hold time did not exceed 1 h (Yanusz et al. 1999; Cleary and Hamazaki 2004; Carlon and Evans 2007). A radio tag was not applied to coho salmon if the live box hold time exceeded 1 h; these fish were counted and released. However, because of low chum salmon catch rates among all fish wheels, there was no hold time restriction for chum that otherwise met the tagging criteria.

Tags were deployed systematically, with a fixed number of tags deployed per day by fish wheel and species. Average historical run timing (1981 to 1984) of chum and coho salmon at Yentna (ADF&G sonar and fish wheel camp at Yentna River rkm 6.7) was used to distribute radio tags by day over the season. The radiotag deployment schedule was based on the average historical

run timing by species from Yentna during 1984 and 1985 when fish wheels operated from early July through early September (Barrett et al. 1985 and Thompson et al. 1986). Only 2 years of similar data were available for Flathorn and may represent less accurate run timing estimates. The Yentna counts were lagged by 1 d to account for the distance (approximately 19 rkm) between Flathorn and Yentna (Yanusz et al. 2007). The proportion of the total run passing on a given day in the historical Yentna data was multiplied by the total number of radio tags available for the season, and rounded off, to determine the number of radio tags to deploy on a given day. Within a day, an equal number of radio tags were deployed among all 4 fish wheels.

With the exception of DCF fish wheel number 1, fish wheels were only operated long enough to catch the necessary number of chum and coho salmon to apply radio tags based on the tagging schedule. As soon as the appropriate number of each species was caught and tagged, fish wheels were stopped during that crew's shift. The DCF operated fish wheel number 1 for approximately 18 h/d and deployed radio tags evenly throughout the hours of operation. All radiotagged fish were measured for METF, sex was determined from external characteristics, and a tissue sample (left axillary process) was collected and preserved in ethanol for later genetic assay. To minimize capture and handling induced stress, no anesthesia was used, fish were held in tubs with fresh river water, and fish were restrained in padded cradles during tagging. Handling time of radiotagged fish averaged <1.5 min.

The radio transmitters used were manufactured by Advanced Telemetry Systems, Inc.[1] (ATS, Isanti, MN) and operated on 18 frequencies within the 150.000 to 151.999 MHz range. Each frequency had up to 50 different transmitting patterns (e.g., pulse codes), resulting in 539 uniquely identifiable transmitters. Transmitters were 50 × 17 mm long, equipped with a 30 cm antenna, and weighed 14 g in air. The battery capacity rating of the transmitters was 126 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 inactive 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.

RADIOTAG RELOCATION

Tracking Stations

Radiotagged chum and coho salmon movement upriver was tracked at 13 river tracking stations placed on major tributaries throughout Susitna River drainage (Figure 1; Table 2). The lower Susitna tracking stations (west and east) were placed below the tagging site to monitor fish migrating downstream after tagging.

Tracking station equipment consisted of an ATS[1] Model 4500 receiver and data logger and a self contained power system. A satellite uplink (Campbell Scientific[1], Logan, Utah) was used with all of the river stations except at Lower Susitna West, Lower Susitna East, Kahiltna, and Deshka. The equipment was housed in a waterproof enclosure and attached to a 9 m mast.

An ATS[1] Model 200 antenna switch was coupled with 2 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.

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

"Reference" radio tags were continuously detected at each station to assure proper station operation. Information was recorded at 10 min intervals.

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 station was located approximately 5.0 km upriver from the tagging site.

Because most of the mainstem tracking stations were located in isolated areas, data were transmitted every hour by satellite uplink to a geostationary operational environmental satellite (GOES) system and relayed to a receiving station near Washington, D.C. (Eiler 1995). Data transmissions were monitored during the field season via the internet. After the field season, the data from each station was downloaded as a comma delimited file to a computer using a Microsoft™ compatible custom program. 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.

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 4520 receiver and data logger and two, 4-element Yagi receiving antennas, one mounted on each side of the aircraft and oriented forward. 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. 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.

RESULTS

RADIOTAG APPLICATION

In 2009, fish wheels were operated from 14 July to 30 August (Table 1). A total of 1,049 chum salmon, of which 239 were radiotagged, were caught among the 4 fish wheels (Table 3). A total of 92 radio tags were deployed in chum salmon from fish wheel number 1, 58 from fish wheel number 2, 36 from fish wheel number 3, and 53 from fish wheel number 4. A total of 3,312 coho salmon, of which 300 were radiotagged, were caught among the 4 fish wheels (Table 3). A total of 95 radio tags were deployed in coho salmon from fish wheel number 1, 77 from fish wheel number 2, 59 from fish wheel number 3, and 69 from fish wheel number 4. Eighty-nine percent (89%) of chum salmon and 91% of coho salmon radio tags were deployed between 26 July and 22 August (Table 4).

Tracking Stations

Tracking stations were installed in the Yentna River drainage between 16 and 18 June and removed between 15 and 17 September 2009. Due to ice damage, the Kahiltna River tracking station was not installed until 7 August and was removed on 17 September. Tracking stations within the Susitna, Talkeetna, and Chulitna rivers were installed between 4 and 24 June and removed between 23 and 25 September 2009.

There were 15 chum salmon and 10 coho salmon final locations (including 53 that never migrated upstream of the gateway station) determined only by ground stations. All radiotagged chum salmon were recorded by at least one tracking station.

Aerial Surveys

Of the 539 radiotagged salmon, 514 final locations (including 53 that never migrated upstream of the gateway station) were assigned based on aerial surveys and corroborated with ground tracking stations. Aerial surveys were conducted over the mainstem Susitna River on 11, 17, 25, and 27 August; 8 and 10 September; 1, 2, and 6 October 2009. Aerial surveys over Yentna River drainage were flown on 12, 26, 27 August; 9 and 10 September; 2, 6, 12, and 16 October 2009. Aerial efforts in 2009 yielded 4 complete drainage-wide surveys. These surveys relocated 522 different radiotagged fish (97.0% of the 539 released). All aerial fish locations were corroborated by available tracking station records. Of the 17 remaining tags, 3 were detected at the Deshka tracking station, 1 at the Kichatna tracking station, 2 at the Lower Yentna tracking station, 10 never migrated past the Susitna Station tracking station and 1 was never detected by either aerial or ground tracking devices.

Spawning Location

Radiotagged chum and coho salmon were assigned a spawning location based on aerial surveys; tracking station data were used only to corroborate these locations. Radiotagged salmon were assigned one of nine movement and migration pattern descriptions (Table 5). This assignment was used to determine the most appropriate final spawning location of each fish. Of the 522 radiotagged salmon relocated by aerial surveys, 38.1% of chum and 50.2% coho salmon displayed progressive and constant upstream movement to their spawning location.

Of the 239 radiotagged chum salmon, 210 (87.8%) could be assigned to a final spawning location (Table 6, Figures 3-7). Of the 300 radiotagged coho salmon, 275 (91.7%) could be assigned a final spawning location (Table 6, Figures 8-12). There were 29 radiotagged chum and 24 coho salmon that never migrated upstream of the Susitna Station tracking station (Table 7 and 8). This tracking station is approximately 5.0 km from the nearest fish wheel and considered the point at which salmon enter the experiment (i.e., "gateway station"). These fish were excluded from the experiment and locations were not reflected in the final distribution map for each species. One radiotagged coho salmon was never relocated by either ground or aerial methods. This fish was tagged on fish wheel number 1 on 8 August.

The final spawning locations indicate that chum and coho salmon were strongly bank oriented at Flathorn. Of the 82 chum salmon tagged on fish wheel number 1, 75 (91.5%) migrated up Yentna River (Figure 4). Of the 47 chum salmon tagged on fish wheel number 4, 45 (95.7%) migrated up Susitna River (Figure 7). Of the 87 coho salmon tagged on fish wheel number 1, 83 (95.4%) migrated up Yentna River (Figure 9). Of the 65 coho salmon tagged on fish wheel number 4, 62 (95.4%) migrated up Susitna River (Figure 12). From fish wheel number 2, 36% of chum salmon and 45% of coho salmon migrated up Yentna River (west channel of the Susitna; Figures 5 and 10). At fish wheel number 3 (east channel of the Susitna River) 87% of chum salmon and 77% of coho salmon migrated up Susitna River (Figures 6 and 11).

Sport anglers voluntarily returned 9 radio tags found in coho salmon. One fish was harvested in the upper Yentna River near Fourth of July Creek. There were 8 fish harvested in the Susitna River drainage: 2 in the Deshka River; and 1 each in Montana, Sheep, Little Willow, and

Sunshine creeks, and 2 in the Talkeetna River (Chunilna and Fish creeks). No radio tags were found in chum salmon harvested during the 2009 fishing season.

A total of 6 Chinook *O. tshawytscha*, 2,366 sockeye *O. nerka*, and 22,607 pink *O. gorbuscha*, salmon were caught by the 4 fish wheels at Flathorn in 2009. Tissue samples were collected from all radiotagged chum (239) and coho salmon (300) and were stored at the ADF&G Gene Conservation Lab in Anchorage, AK.

DISCUSSION

Final spawning site selection for chum and coho salmon appears to be quite disparate. Approximately 62% of the chum salmon utilized river mainstem sites (including only the Susitna, Yentna, and Skwentna river mainstems) versus 42% of the coho salmon. Chum salmon were never documented >2.0 km up the Kahiltna, Deshka, or Tokositna rivers, yet 19% (57) of the radiotagged coho salmon were documented in these rivers. These data are the first Susitna River drainagewide documentation of spawning sites for chum salmon.

Chum salmon more than coho salmon appeared to exhibit movement patterns similar to milling. In 2009, 23.4% of the radiotagged chum salmon displayed either consistent milling in one area (see code 5, Table 5) or a majority of milling with only one outlier location (see code 6, Table 5). However, coho salmon displayed the same pattern among only 15.5% of the radiotagged fish.

Bank orientation was present at the tagging fish wheels for both species. Over 91% of each species migrated up the Yentna River from fish wheel 1 and over 95% of both species migrated up the Susitna River from fish wheel number 4. The geography of the lower Susitna River does not lend itself to moving the tagging location in an effort to get below the point at which chum and coho salmon become bank oriented. Below Flathorn, the Susitna River becomes increasingly braided, shallow, and subject to tidal influence.

There were 29 chum salmon and 24 coho salmon that never migrated upstream of the Susitna Station tracking station during the course of the experiment in 2009. This tracking station was designed to be the "gateway" or entry point to the experiment. It is unclear what caused these salmon not to migrate >3.0 km upstream of Flathorn. Possible causes include: (1) tagging or handling induced stress, (2) physiological stress prior to capture, (3) prospecting behavior from other chum or coho salmon stocks, or (4) these salmon naturally spawn at or below Flathorn. The lower Susitna (east and west) tracking stations were used to record those fish that did not migrate upstream and may otherwise not have been relocated by other means. A total of 5 chum and 4 coho salmon were only recorded at these tracking stations and were not recorded by aerial surveys.

For the distribution of radio tags to accurately describe the true spawning distribution, all chum and coho salmon stocks must have been tagged homogeneously. In this study, radio tags were deployed on a fixed schedule based on average historical run timing. If the actual run timing in 2009 was substantially different from the average, heterogeneous tagging may have occurred. On some days in 2009, some fish wheels did not operate because of extremely low water and not all of the planned radio tags were deployed. This could possibly cause undermarking of stocks passing those sites on those days. The apparent bank orientation by stock and possible heterogeneous catch probabilities among Flathorn fish wheels sites (Yanusz et al. 2007) further

contributes to the chances of heterogeneous marking. There is no way of testing for homogeneous marking in 2009, making any calculations of spawning distribution subject to bias and any inferences subject to doubt.

In 2002, coho salmon were radiotagged in salt water in lower Cook Inlet, avoiding the fish wheel issues (Willette et al. 2003). The raw distribution of radiotagged coho salmon between the Yentna (43%) and Susitna (56%) drainages in this study is very similar to the 46% Yentna and 54% Susitna weighted distribution of radio tags in 2002. The fraction of coho salmon radio tagged in 2002 was compared among 5 streams, and did not differ, suggesting homogenous tagging (Willette et al. 2003). In 1998, coho salmon caught in fish wheels at Yentna were radiotagged (Todd et al. 2001). Of the fish later found in Yentna River, 40% of the radiotagged coho salmon were found in Yentna River mainstem (mainstem plus east and west forks), 30% in Skwentna River, and 10% in Kichatna River. In 2009, the same areas had 35%, 25%, and 12% of the radiotagged coho salmon, respectively. Again, the results are very similar but the issue of bias applies to both studies. Barrett et al. (1984) and Thompson et al. (1986) also radiotagged chum and coho salmon in 1981 and 1982 in the upper Susitna River. They observed similar patterns of mainstem use by chum salmon and tributary use by coho salmon that was repeated in 2009.

Spawning distribution information can be used to improve efficiency and effectiveness for future stock assessment projects. For example, the results from this study are being used in planning for a Susitna River chum and coho salmon capture-recapture abundance estimate in 2010. With this knowledge of spawning distribution, ADF&G will position a new recapture site along the mainstem Susitna River to avoid significant emigration between the capture and recapture sites.

Historical, partial stock assessment data exists for chum and coho salmon for many places in the Susitna watershed (Barrett et al. 1984; Hoffman and Crawford 1986; Thompson et al. 1986; Ivey et al. 2007). As this spawning distribution study continues in subsequent years and the results become more refined and reliable, the historical data could be viewed in the context of the entire watershed, to make it more useful. Additionally, this study is providing genetic baseline samples and better defining the stock composition of Susitna River chum and coho salmon runs. Such information could be useful to ADF&G when gauging land use, fishery management, or invasive species impacts to chum and coho salmon stocks.

ACKNOWLEDGMENTS

We thank the following for their advice and project oversight: Robert Clark, James Hasbrouck and Jack Erickson from DSF in Anchorage. Mark Willette and Robert Decino from DCF in Soldotna supervised the radiotag deployment and fish wheel operations at fish wheel number 1. Christopher Brockman, David Rutz, Annette Oels, and Douglas Miller from DSF in Palmer provided logistical support. Judy Berger, Andy Barclay, and Nick Decovich from the ADF&G Gene Conservation Laboratory (DCF) provided instructions and supplies for collecting tissue samples.

Jan Bullock and Nicholas Logelin in Palmer provided field supervision and logistical support for Flathorn. Vena Stough, Charles Coffey, Alex Inglima, Don Malherek, and Ira Edwards performed the fish wheel sampling at Flathorn for the SFD. Jeffery Kell, Lindsay Goggia, Noah King, Megan Kohler, Joseph Malutin, Sam Roy, and Sheldon Hallmark performed the sampling on fish wheel number 1 at Flathorn for the DSF.

The following people greatly assisted with the logistics of the field operations: Don Glaser (Arctic Wings), Talachulitna Lodge, Northwoods Lodge, and Larry Heater. This project was funded by a Capital Improvement Project from the Alaska State Legislature.

REFERENCES CITED

Barrett, B. M., F. M. Thompson, and S. N. Wick. 1984. Adult anadromous fish investigations: May-October 1983. Susitna Hydro Aquatic Studies. Report No. 1. Alaska Department of Fish and Game, Anchorage.

Barrett, B. M., F. M. Thompson, and S. N. Wicks. 1985. Adult salmon investigations: May-October 1984. Susitna Aquatic Studies Program. Report No. 6. Alaska Department of Fish and Game, APA Document #2748, Anchorage.

Carlon, J. A., and D. Evans. 2007. Abundance of adult coho salmon in the Kenai River, Alaska, 1999-2003. Alaska Department of Fish and Game, Fishery Data Series No. 07-81, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds07-81.pdf

Cleary, P. M., and T. Hamazaki. 2004. Fall chum salmon abundance estimation on the Tanana and Kantishna Rivers using mark recapture techniques, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A04-24, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/RIR.3A.2004.24.pdf

Eiler, J. H. 1995. A remote satellite-linked tracking system for studying Pacific salmon with radiotelemetry. Transactions of the American Fisheries Society 124:184-193.

Hoffman, A. G., and D. L. Crawford. 1986. Susitna River drainage salmon escapement data summary, 1951-1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Susitna Aquatic Studies Program, Report 13, Vol. II, Appendix 1, Anchorage.

Ivey, S., C. Brockman, and D. Rutz. 2007. Overview of the northern Cook Inlet area sport fisheries with proposals under consideration by the Alaska Board of Fisheries, February, 2008. Alaska Department of Fish and Game, Fishery Management Report No. 07-65, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/FMR07-65.pdf

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2007. Alaska Department of Fish and Game, Fishery Data Series No. 10-02, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/Fds10-02.pdf

King, B. E., and S. C. Walker. 1997. Susitna River sockeye salmon fry studies, 1994 and 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A97-26, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/RIR.2A.1997.26.pdf

Shields, P. 2007. Upper Cook Inlet commercial fisheries annual management report, 2007. Alaska Department of Fish and Game, Fishery Management Report No. 07-64, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fmr07-64.pdf

Sweet, D., S. Ivey, and D. Rutz. 2003. Area management report for the recreational fisheries of Northern Cook Inlet, 2001 and 2002. Alaska Department of Fish and Game, Fishery Management Report No. 03-10, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fmr03-10.pdf

Thompson, F. M., S. N. Wick, and B. L. Stratton. 1986. Adult salmon investigations May – October 1985. Alaska Department of Fish and Game, Susitna Hydro Aquatic Studies Report Series 13, Anchorage.

Todd, G. L., S. R. Carlson, P. A. Shields, D. L. Westerman, and L. K. Brannian. 2001. Sockeye and coho salmon escapement studies in the Susitna drainage 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A01-11, Anchorage.

Willette, T. M., R. DeCino, and N. Gove. 2003. Mark-recapture population estimates of coho, pink, and chum salmon runs to upper Cook Inlet in 2002. Alaska Dept. of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A03-20, Anchorage.

REFERENCES CITED (Continued)

Yanusz, R., R. Merizon, D. Evans, M. Willette, T. Spencer, and S. Raborn. 2007. Inriver abundance and distribution of spawning Susitna River sockeye salmon *Oncorhynchus nerka*, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-83, Anchorage. http://www.sf.adfg.state.ak.us/FedAidpdfs/fds07-83.pdf

Yanusz, R. J., S. A. McPherson, and D. R. Bernard. 1999. Production of coho salmon from the Taku River, 1997-1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-34, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-34.pdf

TABLES

Table 1.-Operating dates for Susitna River fish wheels and weirs at Flathorn (rkm 35), 2009.

	Operating dates			
Fish wheel	Weir	Fish wheel		Weir
number	installed	Started	Stopped	removed
1	13-Jul	14-Jul	30-Aug	31-Aug
2	13-Jul	14-Jul	30-Aug	31-Aug
3	13-Jul	14-Jul	30-Aug	31-Aug
4	13-Jul	14-Jul	30-Aug	31-Aug

Table 2.-Location of tracking stations used to monitor the movements of radiotagged chum and coho salmon in Susitna and Yentna River drainages, 2009.

		Distance (km) from	
Drainage	Tracking station	Salt water	Previous station
Susitna	Lower Susitna (West and East)	32.0	na
	Susitna Station	40.0	11.0
	Deshka	63.8	21.8
	Talkeetna River	156.6	28.3
	Upper Susitna River	165.0	36.7
	Chulitna River	170.7	42.4
Yentna	Lower Yentna River	58.1	18.1
	Kahiltna River	93.7	35.6
	Skwentna River	138.5	80.4
	Talachulitna River	144.9	6.4
	Kichatna River	147.3	89.2
	Upper Yentna River	156.0	98.0

Note: "na" = not applicable

Table 3.-Total daily fish wheel effort, catch, and number of radio tags applied by species, Susitna River at Flathorn, 14 July to 30 August 2009.

		Chum salmon		Coho salmon				
			Radio tags		Radio tags	Other salmon catch (no. of fish) [a]		
Date	Fish wheel [b] effort (h)	Catch (no. of fish)	applied (no. of tags)	Catch (no. of fish)	applied (no. of tags)	Chinook salmon	Sockeye salmon	Pink salmon
14-Jul	53.6	2	0	3	0	0	31	140
15-Jul	43.7	0	0	6	0	0	23	121
16-Jul	50.6	3	0	7	0	0	36	108
17-Jul	40.3	0	0	7	0	0	22	166
18-Jul	37.3	3	0	10	2	0	54	370
19-Jul	23.3	2	0	21	1	0	80	383
20-Jul	21.3	8	0	23	2	0	31	221
21-Jul	27.0	36	1	69	1	0	109	655
22-Jul	34.6	26	1	80	2	0	124	1,006
23-Jul	40.9	14	0	91	2	1	104	802
24-Jul	41.7	12	8	104	5	1	74	775
25-Jul	46.5	9	3	88	7	0	82	788
26-Jul	50.3	8	4	119	9	1	71	924
27-Jul	55.0	14	8	94	11	0	47	819
28-Jul	65.1	29	7	154	15	0	96	902
29-Jul	62.4	72	14	240	24	0	141	876
30-Jul	42.2	24	6	86	8	1	62	328
31-Jul	51.4	25	12	112	19	0	89	759
1-Aug	43.2	41	9	88	14	0	175	1,342
2-Aug	41.3	29	8	142	14	0	199	1,761
3-Aug	36.7	41	8	399	13	0	150	1,523
4-Aug	56.3	54	8	368	13	0	124	1,763
5-Aug	43.9	158	8	398	14	0	92	2,438
6-Aug	47.0	176	8	277	11	0	107	1,732
7-Aug	29.8	20	12	23	12	0	53	1,073
8-Aug	33.4	28	12	34	14	1	10	180
9-Aug	40.2	52	15	35	8	0	18	161
10-Aug	35.4	22	7	16	10	0	20	211
11-Aug	37.9	24	10	15	9	0	17	60
12-Aug	24.8	8	6	12	6	0	15	50
13-Aug	17.8	8	7	12	4	0	2	19
14-Aug	16.9	5	4	10	4	0	3	14
15-Aug	39.3	13	6	29	6	0	15	23
16-Aug	34.0	10	7	26	9	0	12	19
17-Aug	38.3	9	6	14	6	0	15	18
18-Aug	27.3	13	4	13	5	0	5	3
19-Aug	50.8	15	6	16	6	0	12	30
20-Aug	25.4	6	2	20	2	0	11	11
21-Aug	53.7	8	5	10	4	1	12	11
22-Aug	37.5	6	5	6	2	0	4	7
23-Aug	27.6	3	2	1	0	0	4	6
24-Aug	20.2	3	2	3	1	0	1	1
25-Aug	41.9	1	0	9	0	0	4	3
26-Aug	9.2	2	2	6	1	0	4	2
27-Aug	23.0	1	1	6	0	0	0	2
28-Aug	7.0	2	2	4	0	0	0	0
29-Aug	19.5	3	2	2	1	0	0	1
30-Aug	20.8	1	1	4	3	0	0	0
Total	1767.3	1,049	239	3,312	300	6	2,360	22,607

[a] No radio tags applied to catch of other salmon species.

[b] Total daily fish wheel effort (all 4 fish wheels combined).

Table 4.-Chum and coho salmon radio tags deployed by week, 2009.

Week	Dates	Number of radio tags deployed	
		Chum salmon	Coho salmon
29	12-16 Jul	0	2
30	20-25 Jul	13	20
31	26 Jul-1 Aug	60	100
32	2-8 Aug	64	91
33	9-15 Aug	55	47
34	16-22 Aug	35	34
35	23-29 Aug	11	3
36	30 Aug-5 Sep	1	3
Total		239	300

Table 5.-Movement and migration pattern descriptions used to determine the final spawning location of radiotagged salmon relocated during aerial surveys in 2009.

Code	Movement description	Chum salmon		Coho salmon	
		Number of radiotagged fish	% of total	Number of radiotagged fish	% of total
1	Did not migrate upstream of Susitna Station.	27	11.7	21	7.2
2	Progressive upstream movement through all aerial surveys.	88	38.1	146	50.2
3	Progressive upstream movement except the last 1-2 aerial surveys, assigned the upstream most location.	32	13.9	34	11.7
4	Initially display upstream movement but then display downstream movement >2 aerial surveys, assigned upstream most location.	19	8.2	11	3.8
5	A cluster of locations (within 20 miles), assigned a known location in the middle of cluster.	39	16.9	34	11.7
6	A cluster of locations except one outlier, assigned location in the middle of cluster, unless the outlier was observed during a late season (>September) survey then it was assigned the upstream most location.	15	6.5	11	3.8
7	Migrated up river A and then had >2 locations up river B. If strong signal strengths (>120) exist among cluster in river B then fish was assigned to river B, otherwise river A.	8	3.5	19	6.5
8	Single aerial relocation only.	3	1.3	6	2.1
9	Sport caught by angler.	0	0.0	9	3.1
	Total	231	100.0	291	100.0

Table 6.-Regional distribution of radiotagged chum and coho salmon in the Susitna and Yentna River drainages, 2009.

		Chum salmon		Coho salmon	
Drainage	Region	Number of radiotagged fish	% of total	Number of radiotagged fish [a]	% of total
Susitna River	Lower Susitna River mainstem [b]	29	12.1	24	8.0
	Deshka River	10	4.2	20	6.7
	Susitna River mainstem	33	13.8	39	13.0
	Willow Creek	6	2.5	3	1.0
	Kashwitna River	4	1.7	0	0.0
	Sheep Creek	5	2.1	5	1.7
	Montana Creek	7	2.9	8	2.7
	Talkeetna River	19	7.9	9	3.0
	Chunilna River	8	3.3	7	2.3
	Sheep River	0	0.0	2	0.7
	Iron Creek	0	0.0	0	0.0
	Prairie Creek / Stephan Lake	0	0.0	1	0.3
	Upper Susitna River mainstem	10	4.2	4	1.3
	Tributaries	0	0.0	0	0.0
	Chulitna River	9	3.8	32	10.7
	Byers Lake	0	0.0	3	1.0
	Tokositna River	0	0.0	11	3.7
	Swan Lake	0	0.0	1	0.3
Yentna River	Yentna River mainstem	18	7.5	32	10.7
	Kahiltna River	0	0.0	14	4.7
	Peters Creek	0	0.0	11	3.7
	Lake Creek	5	2.1	6	2.0
	Chelatna Lake	0	0.0	1	0.3
	Lower Skwentna River mainstem	43	18.0	16	5.4
	Tributaries	0	0.0	0	0.0
	Shell Creek / Lake	1	0.4	0	0.0
	Talachulitna River	6	2.5	8	2.7
	Talachulitna Creek / Judd Lake	2	0.8	7	2.3
	Upper Skwentna River mainstem	0	0.0	0	0.0
	Tributaries	1	0.4	1	0.3
	Hewitt Creek / Lake	0	0.0	1	0.3
	Johnson Creek	1	0.4	5	1.7
	Kichatna River	8	3.3	15	5.0
	West Fork Yentna River	13	5.4	11	3.7
	East Fork Yentna River	1	0.4	2	0.7
	Total	239	100.0	299 [a]	100.0

[a] One radio tag deployed at fish wheel number 1 was never detected via aerial or ground relocation efforts.

[b] Lower Susitna radio tags account for all radiotagged fish that did not migrate above the gateway station (Susitna Station).

Table 7.-Unweighted terminal distribution (number of fish and percent) of radiotagged chum salmon in the Susitna River drainage by fish wheel, 2009.

Fish wheel number	Lower Susitna [a]	Susitna River	Eastside Parks Hwy [b]	Deshka River	Talkeetna River	Chulitna River	Tokositna River	Yentna River	W. Fork Yentna River	Kahiltna River	Lake Creek	Skwentna River	Talachulitna River	Johnson Creek	Kichatna River	Total
1	10	4	1	0	2	0	0	14	8	0	2	39	5	0	7	92
	10.9%	4.3%	1.1%	0.0%	2.2%	0.0%	0.0%	15.2%	8.7%	0.0%	2.2%	42.4%	5.4%	0.0%	7.6%	100.0%
2	8	14	4	7	5	2	0	4	2	0	3	5	2	1	1	58
	13.8%	24.1%	6.9%	12.1%	8.6%	3.4%	0.0%	6.9%	3.4%	0.0%	5.2%	8.6%	3.4%	1.7%	1.7%	100.0%
3	5	9	6	0	11	1	0	0	2	0	0	1	1	0	0	36
	13.9%	25.0%	16.7%	0.0%	30.6%	2.8%	0.0%	0.0%	5.6%	0.0%	0.0%	2.8%	2.8%	0.0%	0.0%	100.0%
4	6	16	11	3	9	6	0	1	1	0	0	0	0	0	0	53
	11.3%	30.2%	20.8%	5.7%	17.0%	11.3%	0.0%	1.9%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Combined total:																
Number	29	43	22	10	27	9	0	19	13	0	5	45	8	1	8	239
Percent	12.1%	18.0%	9.2%	4.2%	11.3%	3.8%	0.0%	7.9%	5.4%	0.0%	2.1%	18.8%	3.3%	0.4%	3.3%	100.0%

[a] Lower Susitna radio tags account for all radiotagged fish that did not migrate upstream of the "gateway" tracking station (Susitna Station).

[b] Includes: Willow Creek, Kashwitna River, Sheep Creek, and Montana Creek that drain into the Susitna River along the Parks Highway.

Table 8.-Unweighted terminal distribution (number of fish and percent) of radiotagged coho salmon in the Susitna River drainage by fish wheel, 2009.

Fish wheel number	Lower Susitna [a]	Susitna River	Eastside Parks Hwy [b]	Deshka River	Talkeetna River	Chulitna River	Tokositna River	Yentna River	W. Fork Yentna River	Kahiltna River	Lake Creek	Skwentna River	Talachulitna River	Johnson Creek	Kichatna River	Total
1 [c]	7	0	2	1	0	1	0	21	5	17	4	10	9	5	12	94
	7.4%	0.0%	2.1%	1.1%	0.0%	1.1%	0.0%	22.3%	5.3%	18.1%	4.3%	10.6%	9.6%	5.3%	12.8%	100.0%
2	6	14	2	5	5	7	6	6	5	7	1	5	5	0	3	77
	7.8%	18.2%	2.6%	6.5%	6.5%	9.1%	7.8%	7.8%	6.5%	9.1%	1.3%	6.5%	6.5%	0.0%	3.9%	100.0%
3	7	11	5	6	5	11	2	7	1	1	1	1	1	0	0	59
	11.9%	18.6%	8.5%	10.2%	8.5%	18.6%	3.4%	11.9%	1.7%	1.7%	1.7%	1.7%	1.7%	0.0%	0.0%	100.0%
4	4	18	7	8	9	16	4	1	0	0	1	1	0	0	0	69
	5.8%	26.1%	10.1%	11.6%	13.0%	23.2%	5.8%	1.4%	0.0%	0.0%	1.4%	1.4%	0.0%	0.0%	0.0%	100.0%
Combined total:																
Number	24	43	16	20	19	35	12	35	11	25	7	17	15	5	15	299
Percent	8.0%	14.4%	5.4%	6.7%	6.4%	11.7%	4.0%	11.7%	3.7%	8.4%	2.3%	5.7%	5.0%	1.7%	5.0%	100.0%

[a] Lower Susitna radio tags account for all radiotagged fish that did not migrate upstream of the "gateway" tracking station (Susitna Station).

[b] Includes: Willow Creek, Kashwitna River, Sheep Creek, and Montana Creek that drain into the Susitna River along the Parks Highway.

[c] One radio tag deployed at fish wheel number 1 was never detected thereafter by aerial or ground relocation efforts.

FIGURES

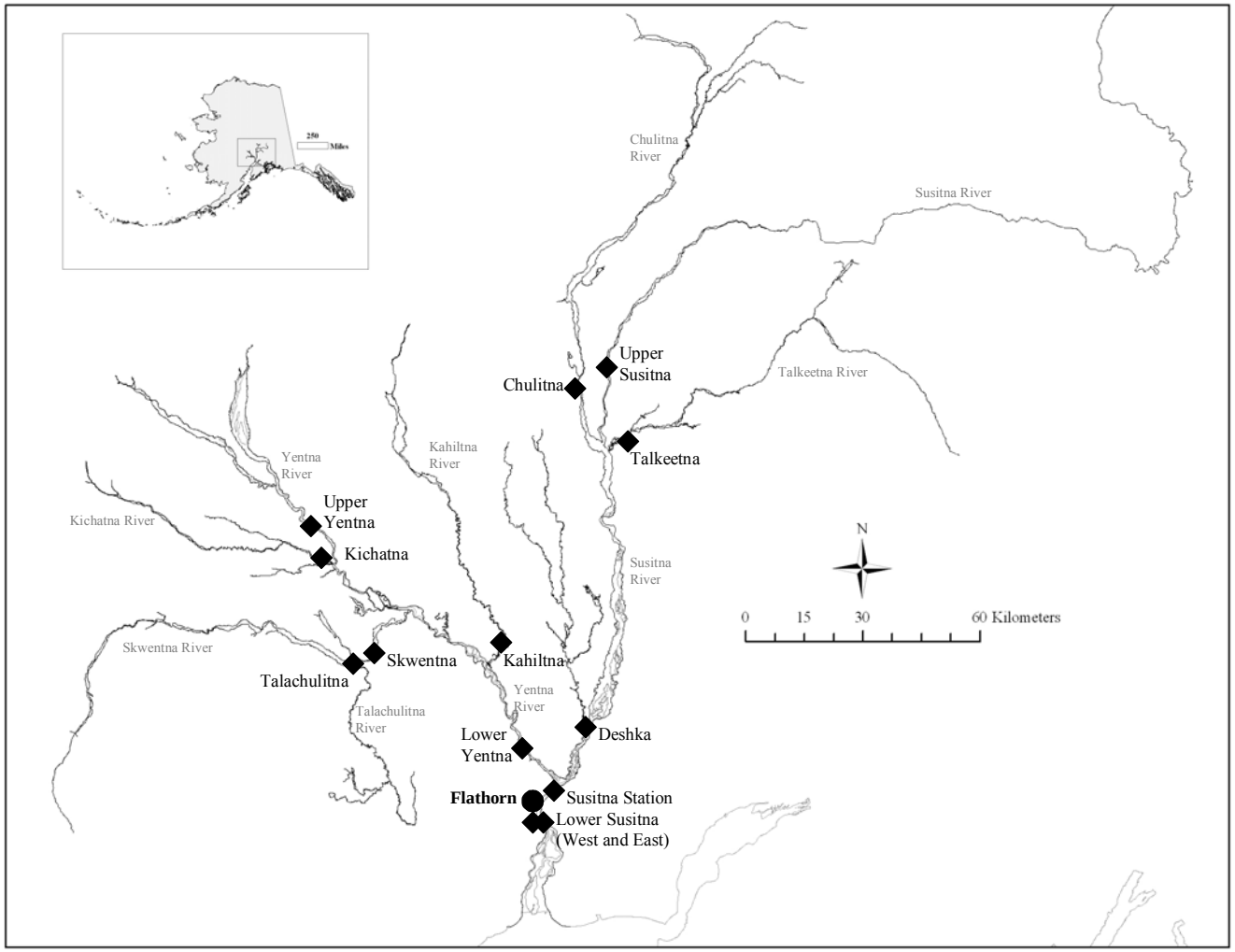

Figure 1.-Location of Flathorn tagging site (circle) and fixed radiotracking stations (diamonds) in the Susitna River drainage, 2009.

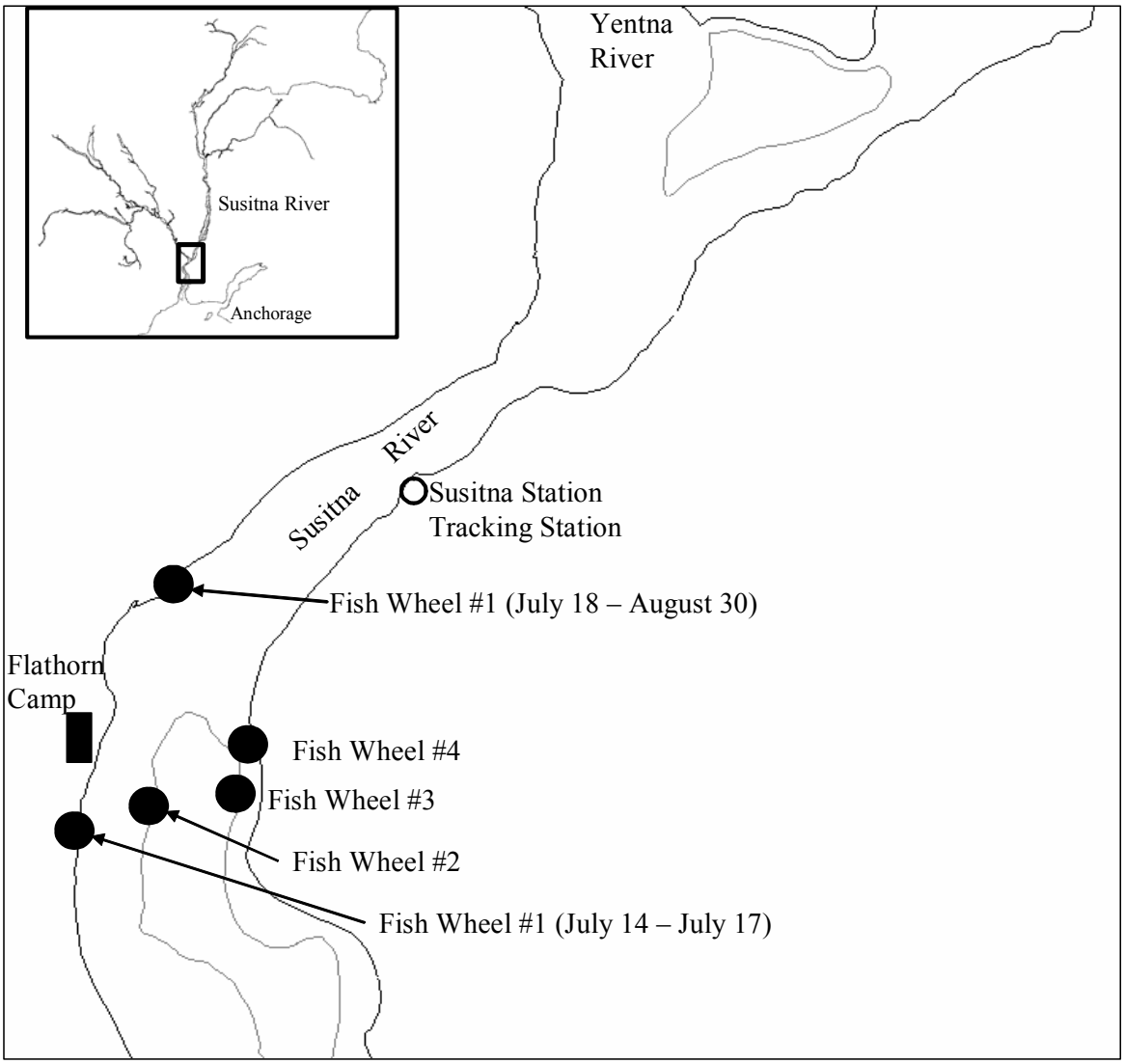

Figure 2.-Location of Flathorn fish wheels (circles), Flathorn Camp (rectangle), and radiotracking station (open circle), 2009.

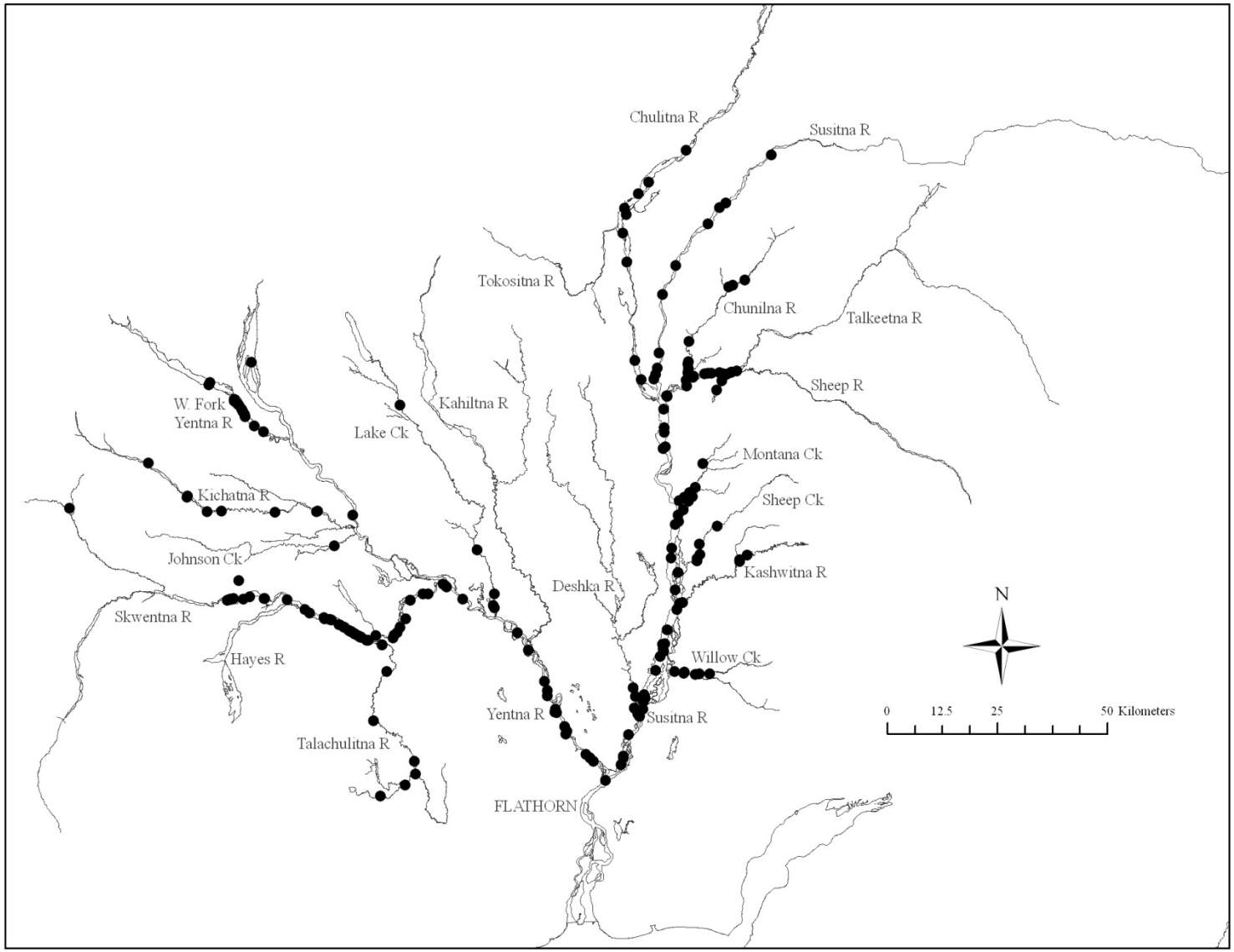

Figure 3.-Final spawning distribution of chum salmon radiotagged at all fish wheels in 2009.

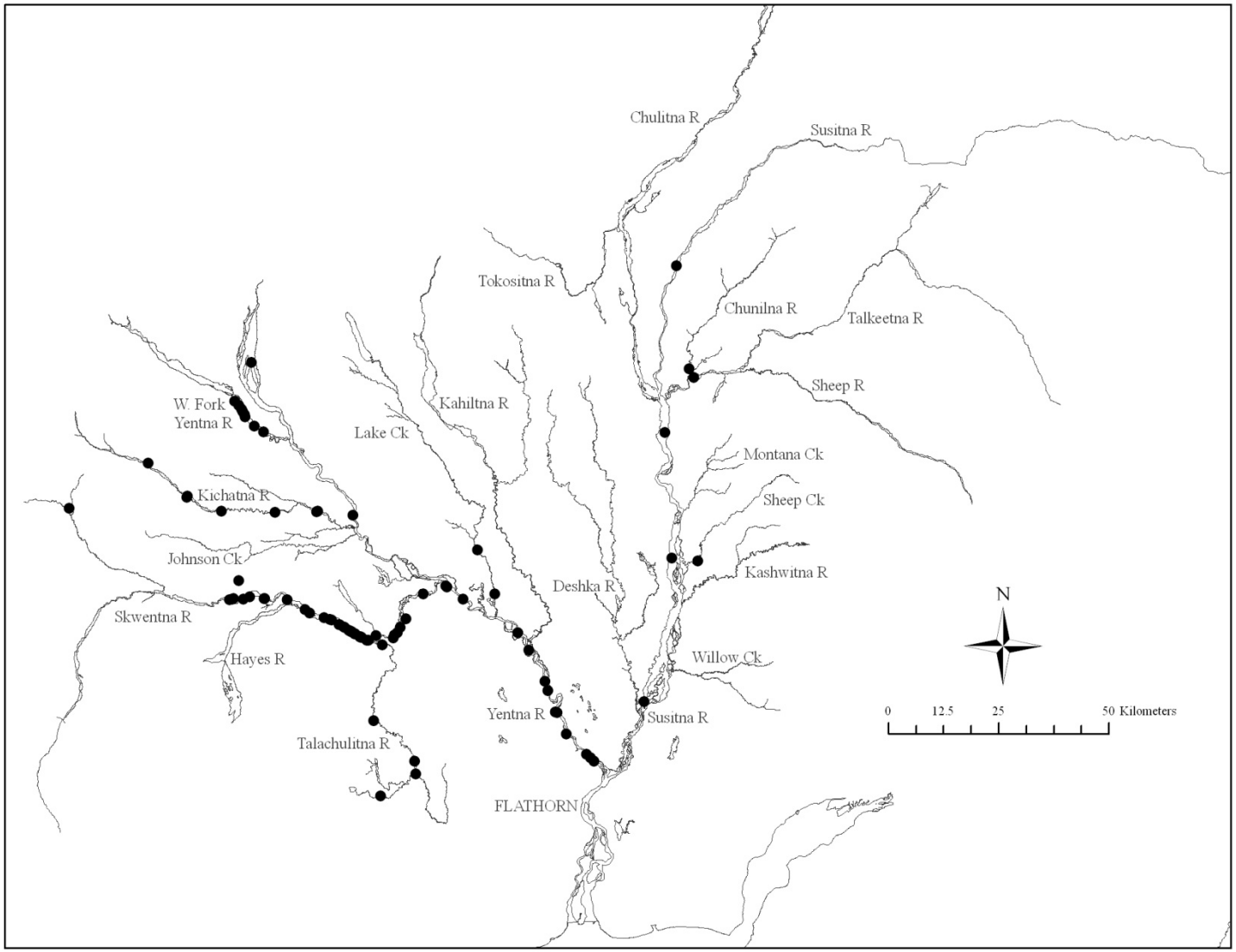

Figure 4.-Final spawning distribution of chum salmon radiotagged at fish wheel number 1, 2009.

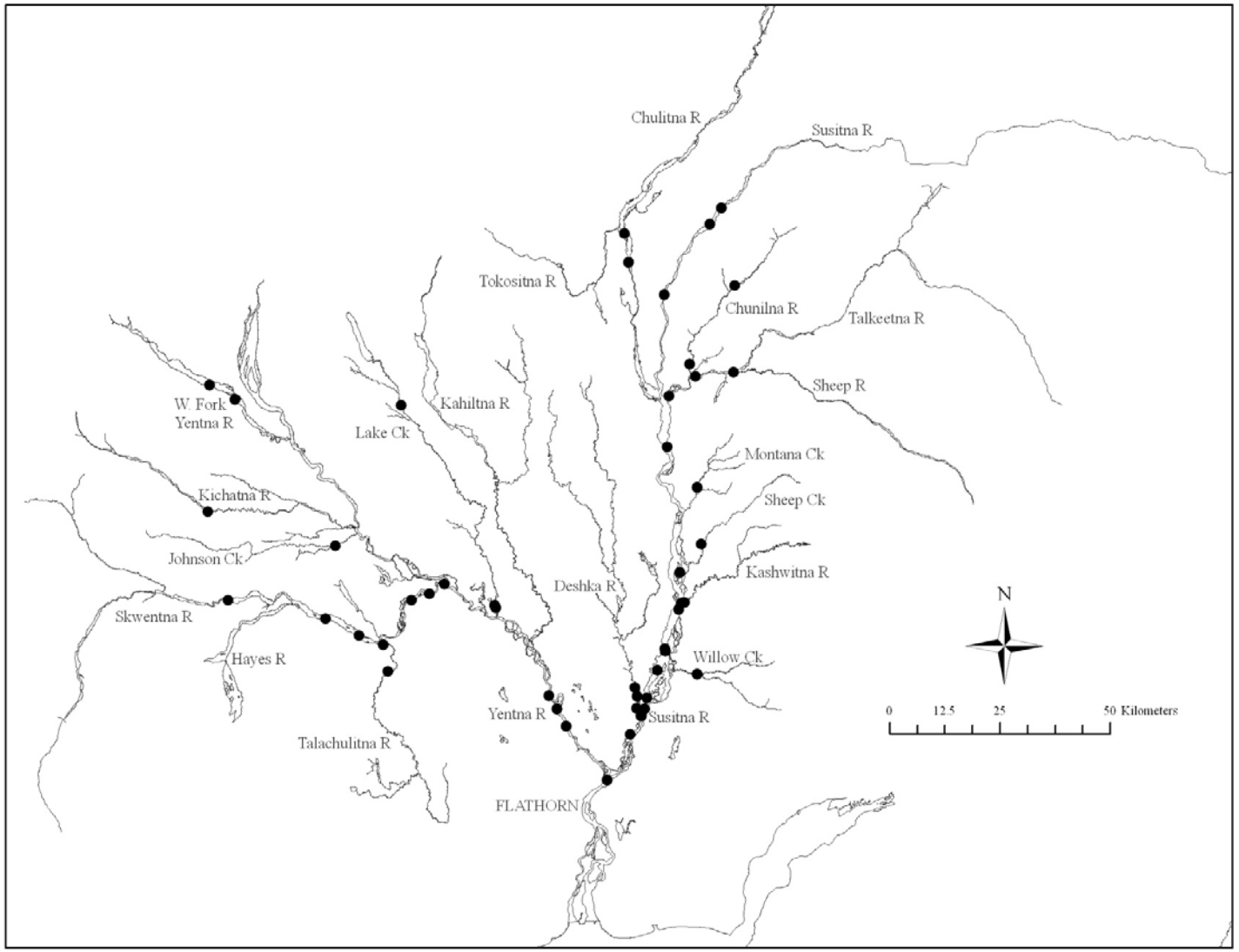

Figure 5.-Final spawning distribution of chum salmon radiotagged at fish wheel number 2, 2009.

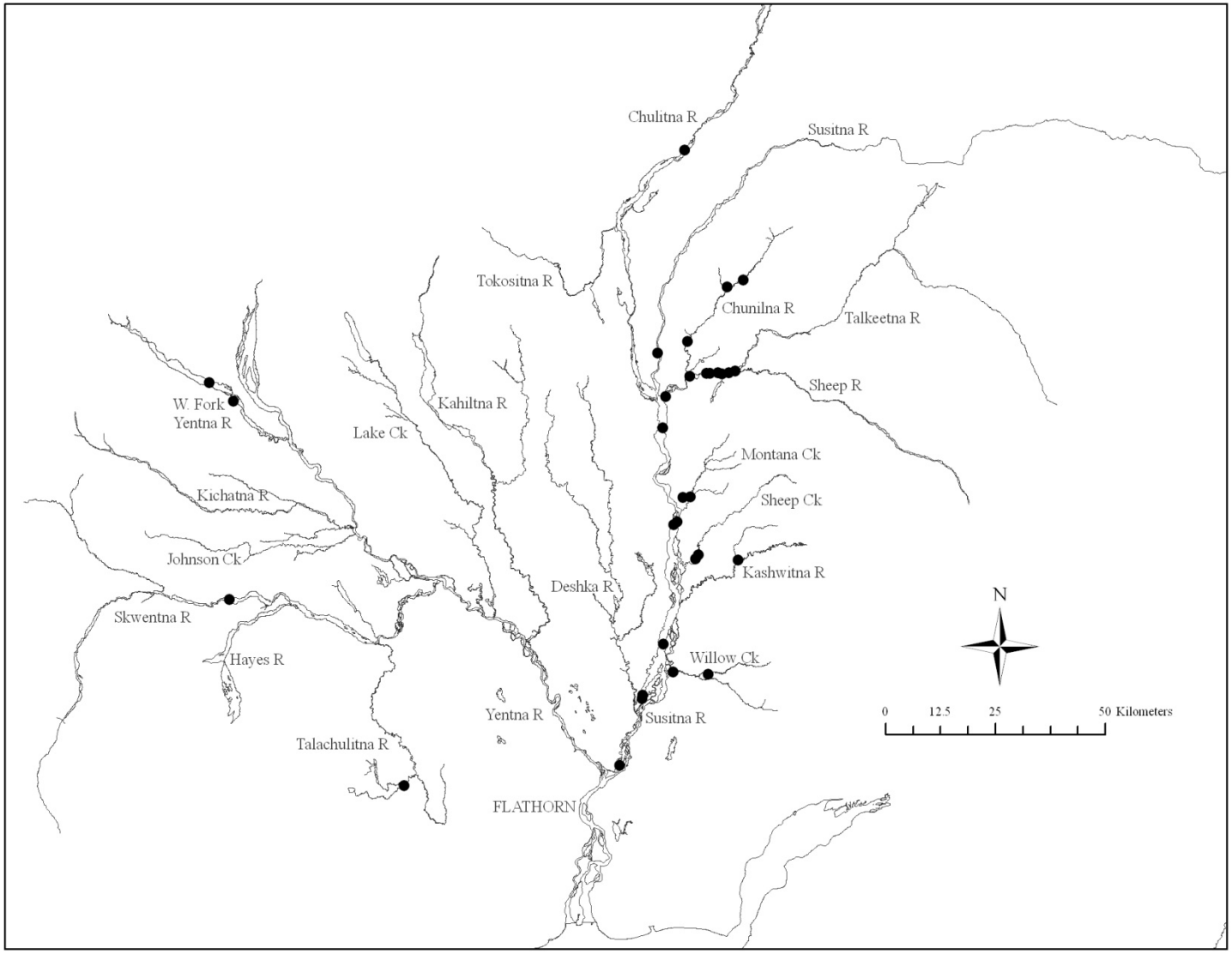

Figure 6.-Final spawning distribution of chum salmon radiotagged at fish wheel number 3, 2009.

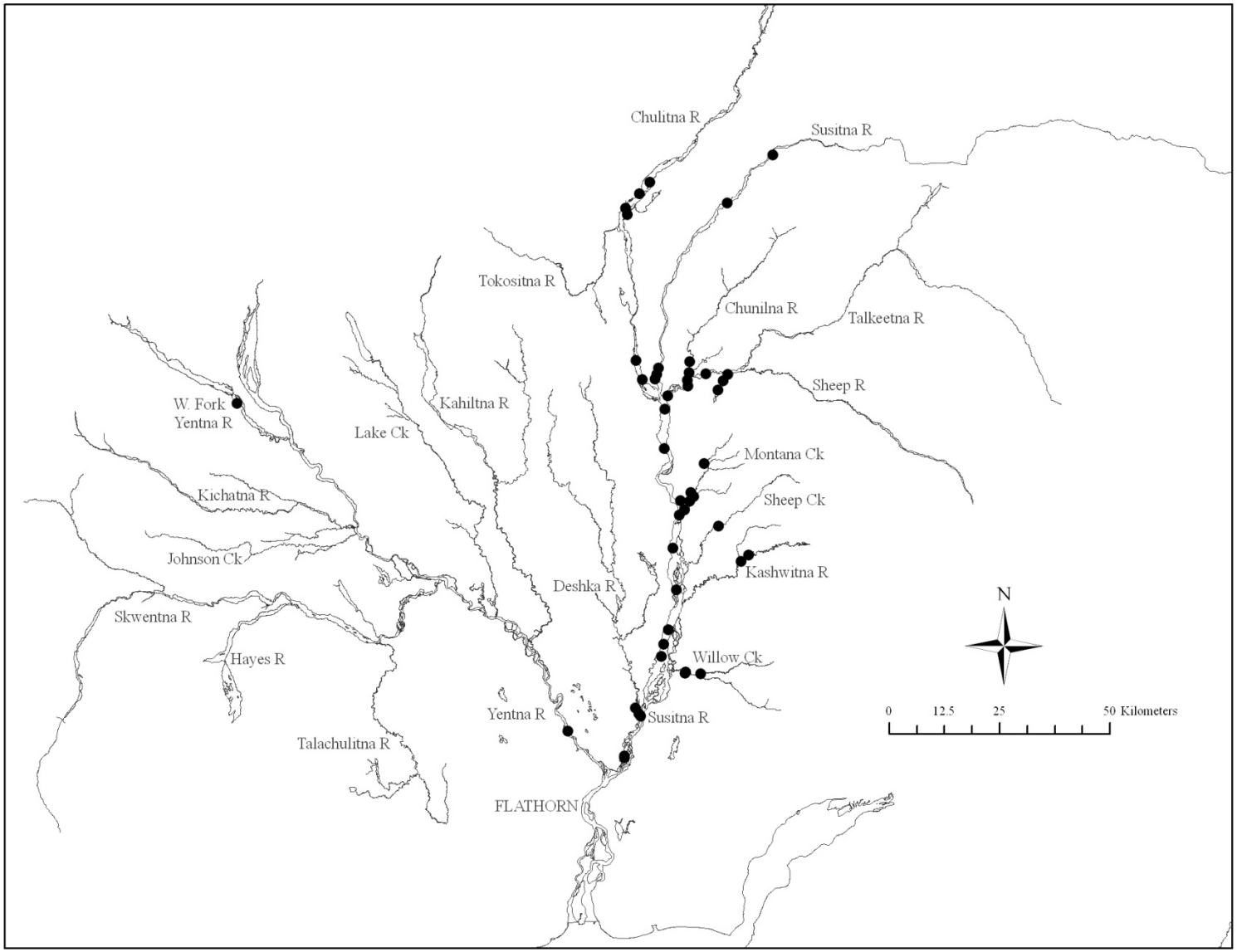

Figure 7.-Final spawning distribution of chum salmon radiotagged at fish wheel number 4, 2009.

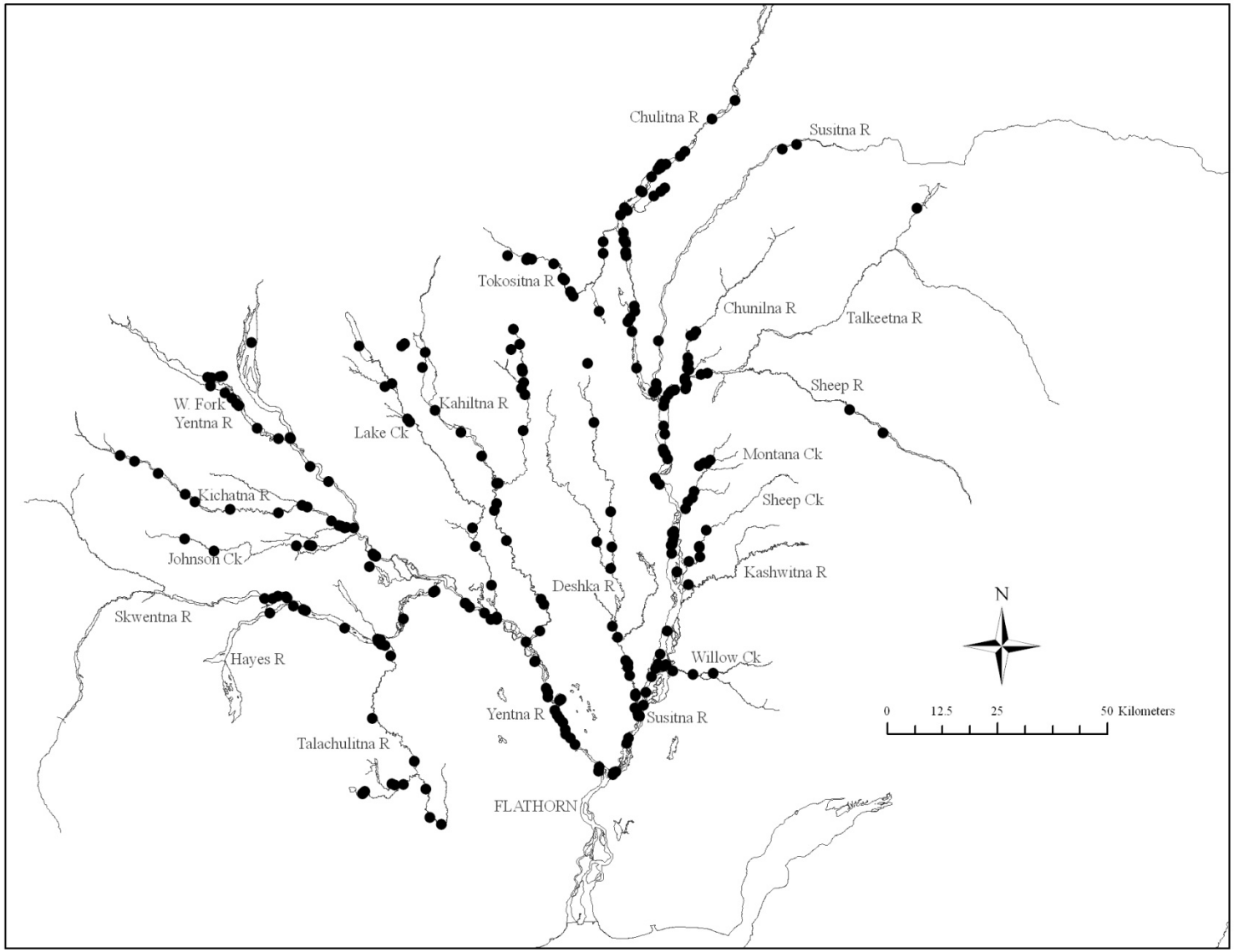

Figure 8.–Final spawning distribution of coho salmon radiotagged at all fish wheels in 2009.

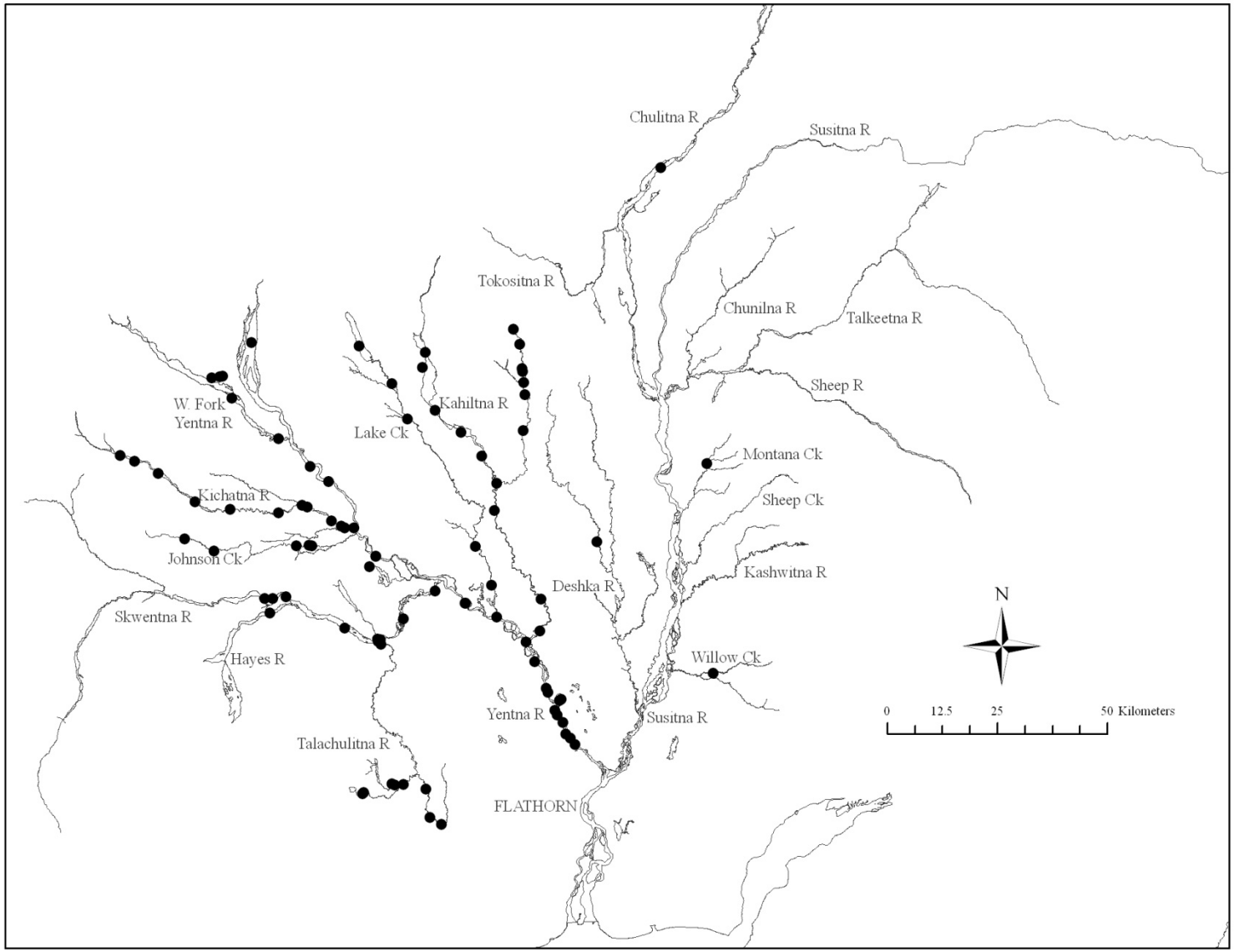

Figure 9.-Final spawning distribution of coho salmon radiotagged at fish wheel number 1, 2009.

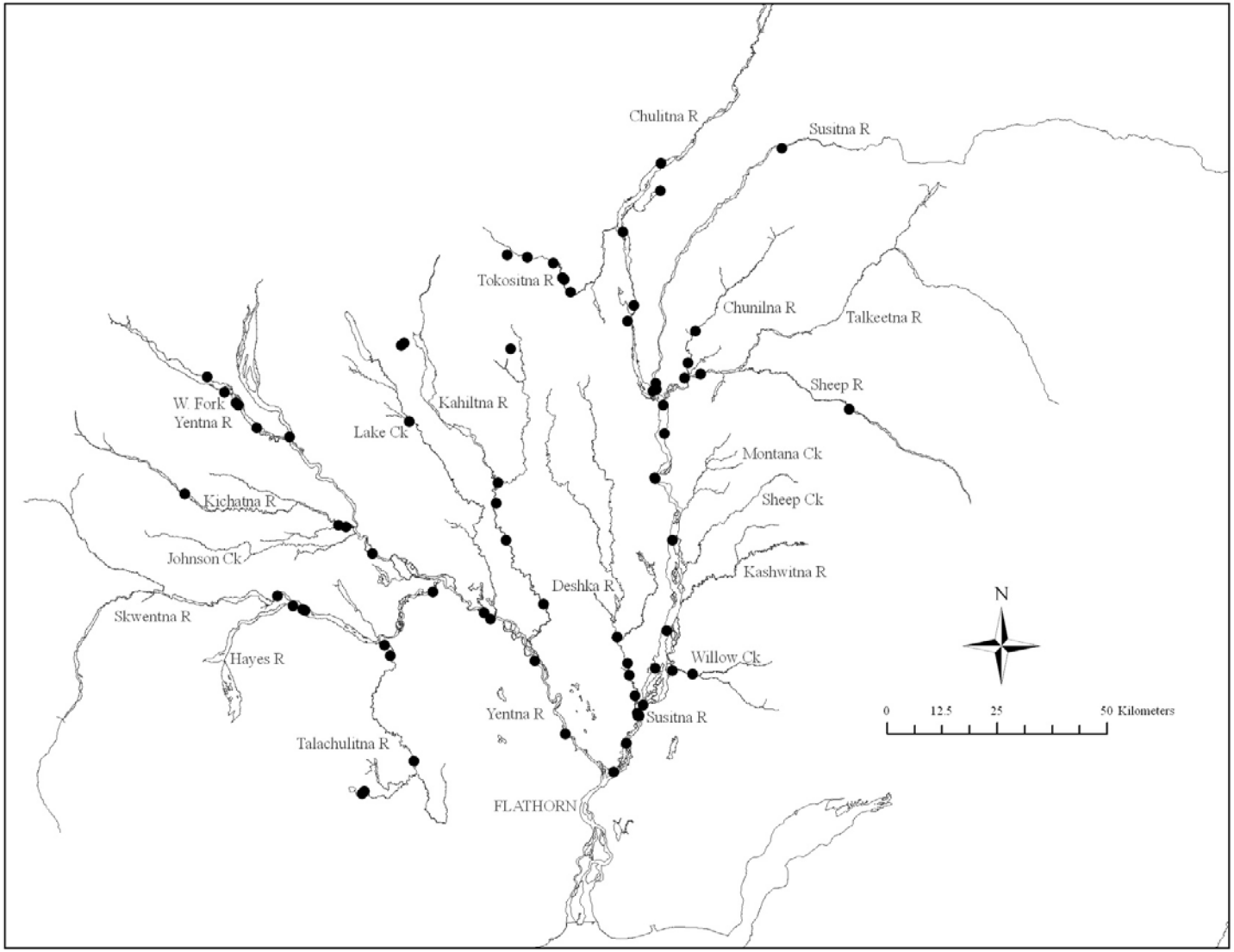

Figure 10.-Final spawning distribution of coho salmon radiotagged at fish wheel number 2, 2009.

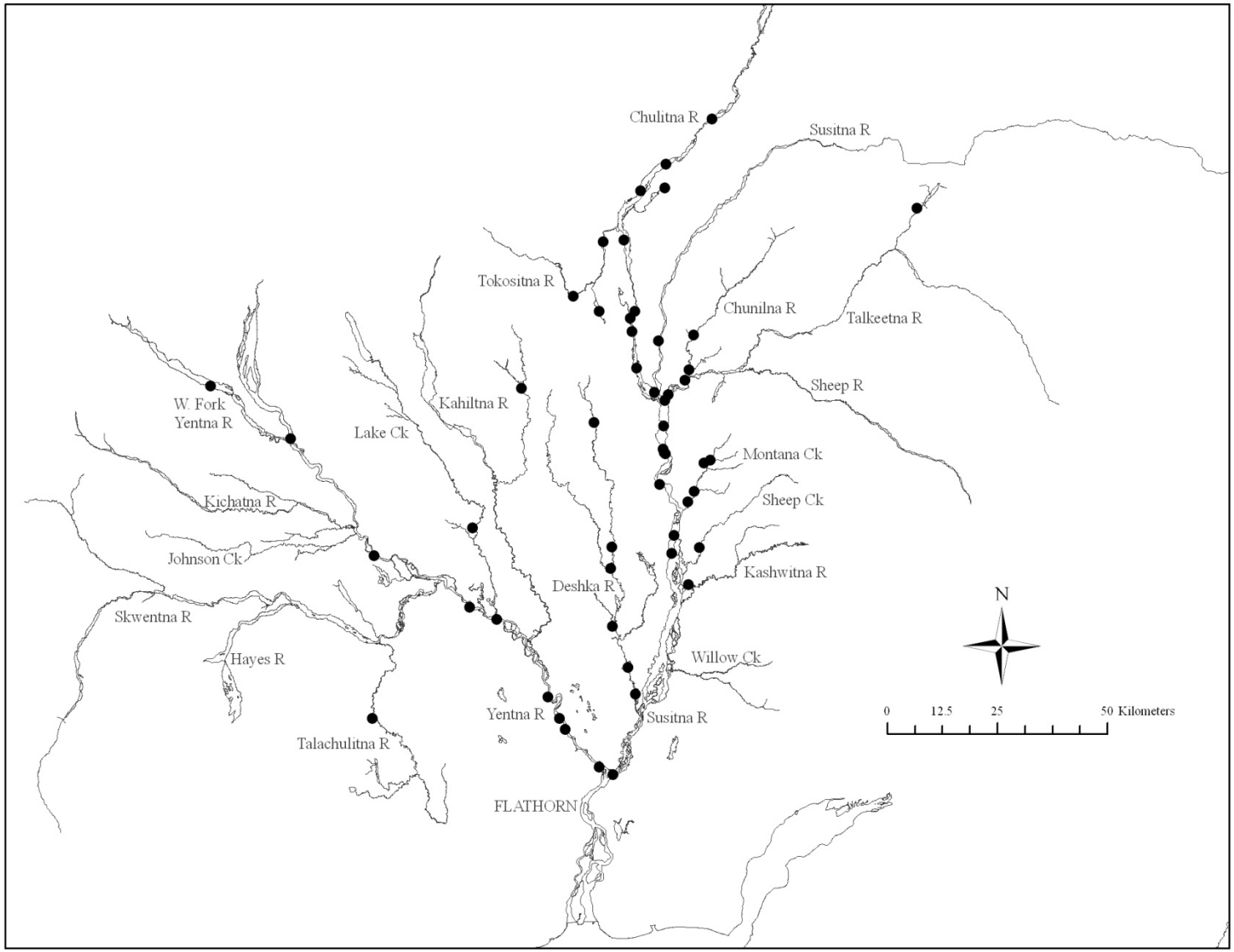

Figure 11.-Final spawning distribution of coho salmon radiotagged at fish wheel number 3, 2009.

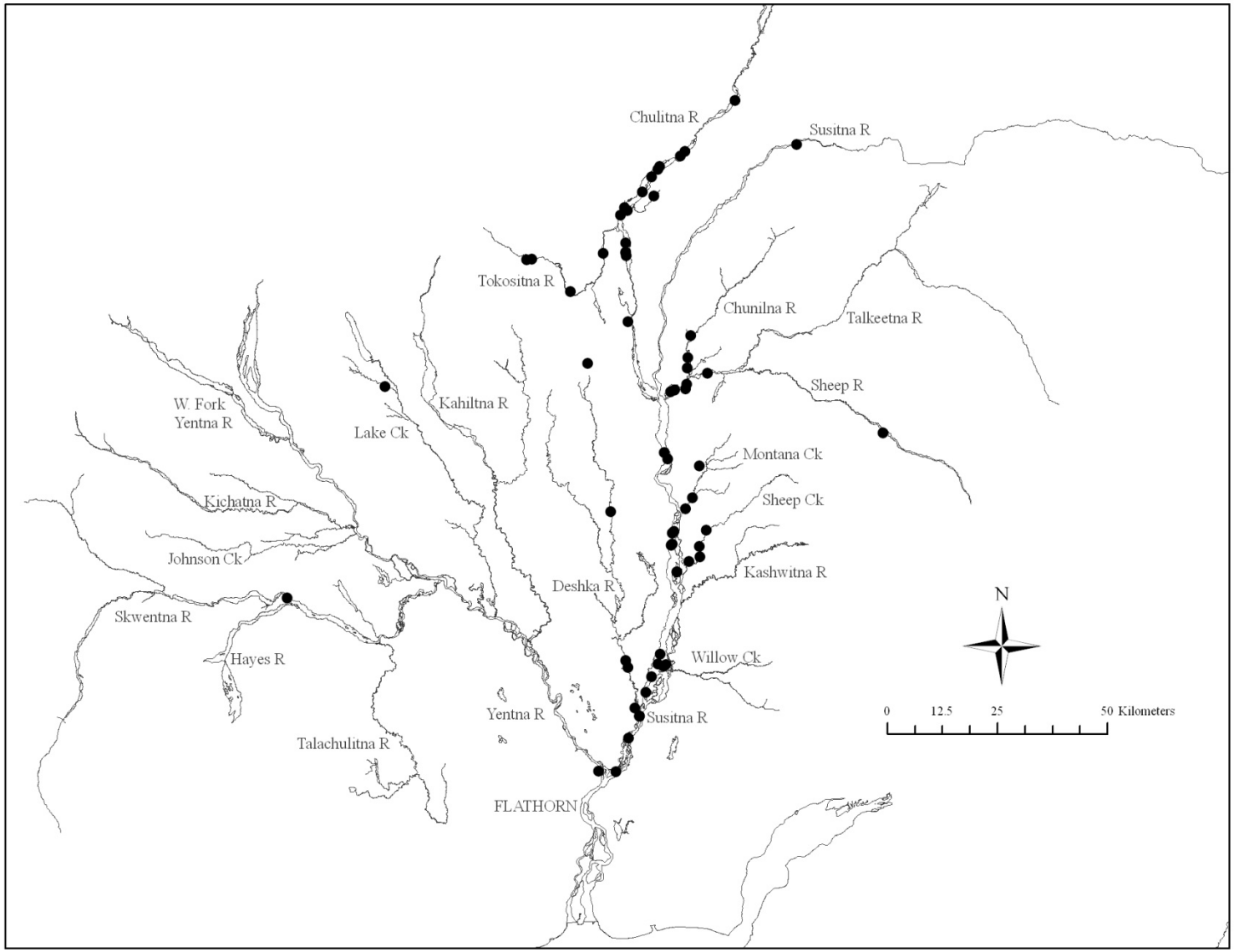

Figure 12.-Final spawning distribution of coho salmon radiotagged at fish wheel number 4, 2009.