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Migratory Timing and Distribution of Kenai River Chinook Salmon Using Radio Telemetry, 2014–2015

by

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and

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February 2017

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

Symbols and Abbreviations

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

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

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. 17-03

MIGRATORY TIMING AND DISTRIBUTION OF KENAI RIVER CHINOOK SALMON USING RADIO TELEMETRY, 2014–2015

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ABSTRACT

The migratory timing and distribution of Kenai River Chinook salmon was examined using radio telemetry for 2014 and 2015. Spawning destinations were determined for 153 Chinook salmon in 2014 and 39 in 2015. Radiotagging data since 2010 are presented with data from 2014 and 2015 when appropriate. Of the Chinook salmon radiotagged during the early run in 2014, 81% (SE 4%) spawned in tributaries (range 72–85% since 2010). Radiotagged tributary-spawning Chinook salmon primarily spawned in the Killey River, Benjamin Creek, and Funny River during all years. Estimated Killey River Chinook salmon escapements based on weir passage and radiotag distribution within the Killey River drainage ranged from 3,564 (SE 500) to 3,934 (SE 627) during 2012–2015. In 2014, all but 2 Chinook salmon radiotagged during the late run (after 30 June) spawned in the mainstem of the Kenai River. The highest proportion of radiotagged mainstem spawners in 2014 were downstream of the Soldotna Bridge at RM 21 (39% SE 6%) and between the Moose River confluence at river mile (RM) 36.3 and Skilak Lake outlet at RM 50 (36% SE 6%). During 2012–2014, an average of 4.0% (SE 1.2%) of assigned mainstem spawning destinations were downstream of the RM 13.7 Chinook salmon sonar. For tributary spawners during 2010–2014, 69% and 95% were in waters with existing closures and restrictions upstream of Slikok Creek on July 1 and July 15, respectively. On 1 July, 23% of tributary spawners were in waters open to fishing upstream of Slikok Creek and 8% were downstream of Slikok Creek. In July, mainstem-spawning Chinook salmon radiotagged in 2012–2014 were primarily (51–59%) in waters open to fishing downstream of Slikok Creek; the rest were upstream: 23–30% in unrestricted waters and 12–20% in closed or restricted waters.

Key words: Kenai River, Chinook salmon, *Oncorhynchus tshawytscha*, radiotelemetry, stock composition, spawning distribution, run timing

INTRODUCTION

The Kenai River watershed encompasses approximately 2,200 square miles of the Kenai Peninsula including diverse landscapes such as glaciers, lakes, mountains, and lowlands. The Kenai River mainstem is approximately 82 miles long including a 15-mile stretch through Skilak Lake (Figure 1). Tidal influence extends upstream to river mile (RM) 12. The Kenai River supports populations of Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), Dolly Varden (*Salvelinus malma*), and rainbow trout (*O. mykiss*). Kenai River Chinook salmon are particularly prized due to their large size (Roni and Quinn 1995) and support popular and valuable recreational fisheries (Perschbacher 2015a). Regulations are complex and highly refined, as appropriate for a heavily utilized fishery.

Radiotelemetry studies have been conducted on Kenai River Chinook salmon during 1979–1981 (Burger et al. 1983), 1984 (Hammarstrom et al. 1985), 1989–1991 (Bendock and Alexandersdottir 1992), and most recently 2010–2013 (Reimer 2013). The most recent studies deployed many more radio tags than had been deployed in earlier years.

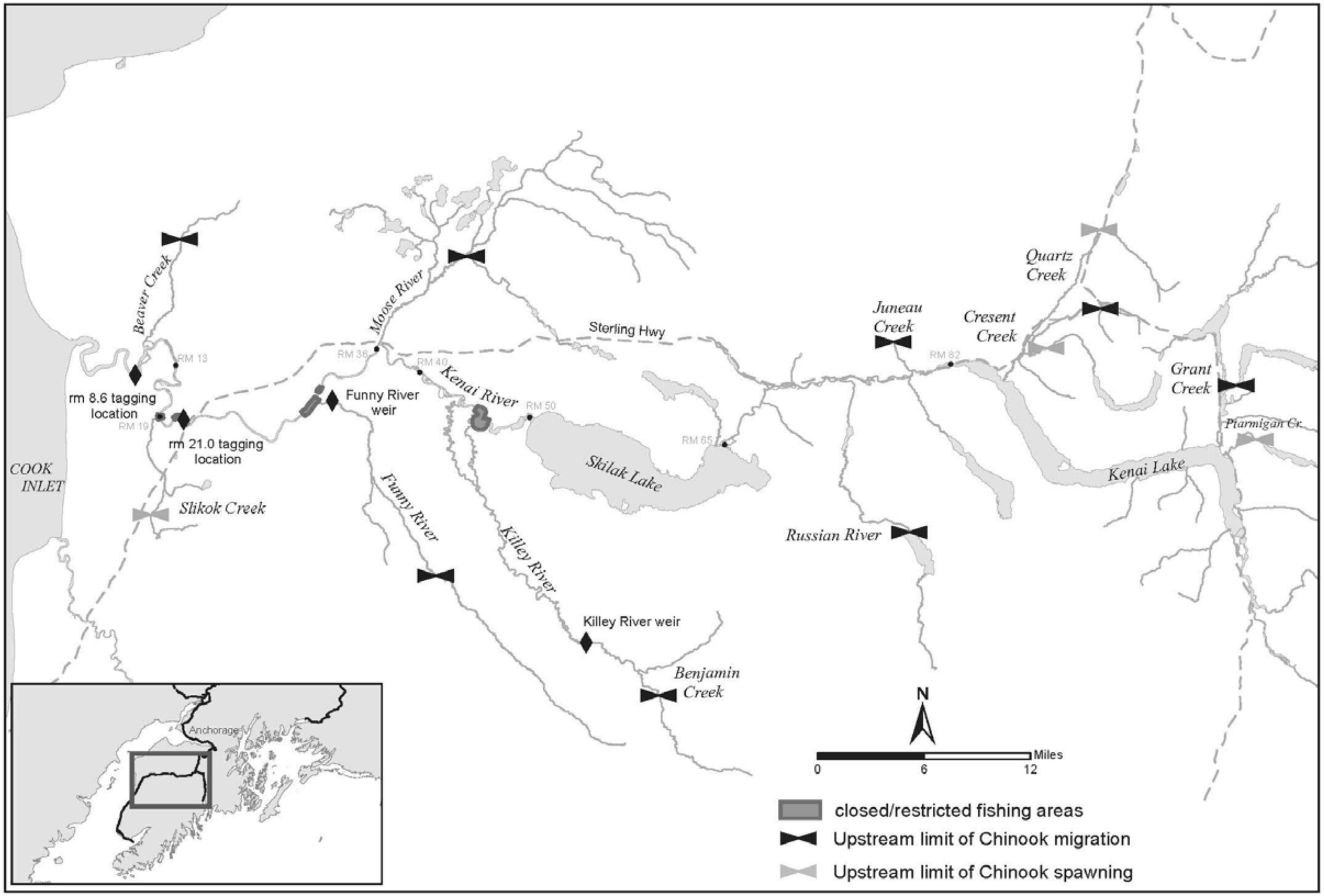

Figure 1.–The Kenai River drainage.

Note: The area closed to Chinook salmon fishing near the confluence of Slikok Creek and the Kenai River, and the boat-restricted fishing areas near the Soldotna Bridge and near the confluence of the Moose and Kenai Rivers are obscured due to their small size relative to the scale of the map. The area closed to Chinook salmon fishing in the mainstem Kenai River upstream of Skilak Lake and in the tributaries to the Kenai River are not identified here to reduce clutter.

Kenai River Chinook salmon are separated spatially and genetically into tributary and mainstem-spawning populations (Bendock and Alexandersdottir 1992; Burger et al. 1983; McKinley et al. 2013; Reimer 2013; Reimer et al. 2016). Tributaries of the Kenai River that support populations of Chinook salmon include Slikok Creek, Funny River, Killey River, Russian River, Juneau Creek, Quartz Creek, Ptarmigan Creek, and Grant Creek. Benjamin Creek, a tributary of the Killey River, and Crescent and Daves creeks, tributaries of Quartz Creek, also contain Chinook salmon. Chinook salmon have also been observed in Beaver Creek and Moose River although sightings may have been of strays rather than of spawning populations[1] (Elliott and Finn 1984; Booth and Otis 1996). The Killey River supports the largest tributary-spawning population, followed by Funny River. Other drainages support considerably smaller spawning populations than the Killey and Funny rivers.

Nearly all of the Kenai River mainstem upstream of the intertidal area (above approximately RM 12) is suitable spawning habitat for Chinook salmon (Burger et al. 1983; Johnson and Daigneault 2013; Reimer 2013). The spawning distribution of Chinook salmon within the mainstem Kenai River has been quantified by dividing the river into 4 sections (Figure 1): RM 12–21 (downstream of the Sterling Highway Bridge in Soldotna), RM 21–36.3 (Soldotna Bridge to Moose River confluence), RM 36.3–50 (Moose River confluence to Skilak Lake) and RM 65–82 (Skilak Lake to Kenai Lake). Chinook salmon spawn in all sections; however, the furthest downstream section supports the highest density of spawners per mile of any section (Reimer 2013). Recent management actions have used the Moose River confluence and the downstream end of the Slikok Creek sanctuary as boundaries for restricting the sport fishery.

Tributary-spawning Chinook salmon primarily arrive from May to early July (Reimer et al. 2016). Mainstem-spawning Chinook salmon primarily arrive from mid-June to mid-August. Although there is overlap in the run timing of tributary and mainstem-spawning populations, Kenai River Chinook salmon are separated temporally for management purposes into 2 runs (early and late) that roughly represent tributary (early) and mainstem (late) populations. Early-run fish are classified as those that enter the river prior to 1 July and late-run fish are those that enter the river on or after 1 July. Early-run Chinook salmon are less numerous than late-run Chinook salmon (Fleischman and McKinley 2013; McKinley and Fleischman 2013). Management plans and escapement goals are in place for both runs. The early-run optimum escapement goal range (OEG; set by the Alaska Board of Fisheries) is currently 5,300–9,000 Chinook salmon. The late run sustainable escapement goal range (SEG; set by ADF&G) is currently 15,000–30,000 Chinook salmon. The management plans for each run require timely predictions of escapement, as well as age composition data to develop brood tables necessary for stock–recruit assessment. In the past 20 years, the 1997, 1998, 2000, 2002, and 2010–2015 early runs, and the 1998, 2011–2015 late runs were restricted to meet escapement goals.

The size of the inriver run is a key component for estimating spawning escapement and implementing management plans. Acoustic assessment of Chinook salmon abundance in the Kenai River has used technologies and techniques that are continuously refined in an effort to improve fish species classification. The Chinook salmon sonar site has been located at RM 8.6 since it was established in 1985 (Eggers et al. 1995). See Key et al. (2016) for a comprehensive history of sonar research and development at the Kenai River RM 8.6 Chinook salmon sonar site.

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[1] Both Beaver Creek and Moose River were surveyed over 2 years. In both cases, a few fish were located in one season and no fish were located in the other.

ADF&G began testing another sonar site at RM 13.7 during 2012 and operated a sonar there in 2013 (Miller et al. 2016). This new site has many advantages over the RM 8.6 site; it is located above tidal influence and it has the potential to achieve bank-to-bank coverage of the river with sonar, which was not possible at the RM 8.6 site. However, a limited number of Chinook salmon spawn downstream of RM 13.7, which is quantified via radiotagging of Chinook salmon in this report.

The U.S. Fish and Wildlife Service (USFWS) has operated a weir on the Funny River since 2006 (Boersma and Gates 2016) and a weir on the Killey River since 2012 (Gates and Boersma 2016). The Funny River weir is located approximately 1.2 RM upstream of the confluence with the Kenai River and counts provide a near census of Funny River escapement (Reimer 2013). The Killey River weir is located approximately 28 RM upstream of the confluence with the Kenai River and significant spawning occurs downstream of the weir (Reimer 2013). Radiotagged Chinook salmon have been used to determine the proportion of Killey River Chinook salmon that migrated upstream of the weir. Funny River and Killey River Chinook salmon represented 68–78% of all early-run fish radiotracked during 2010–2013 (Reimer 2013). Thus, Funny River weir passage and Killey River escapement estimates coupled with other tributary weir data provide a coarse minimum value for early-run abundance estimates generated by the sonar.

FISHING REGULATIONS

Fishery regulations are more conservative during the early run than during the late run. For example, bait is not allowed prior to 1 July in the Kenai River and Chinook salmon between 42 and 55 inches total length cannot be retained prior to 1 July. In addition, these conservative regulations remain effective upstream of an ADF&G marker located approximately 300 yards downstream of the Kenai River–Slikok Creek confluence at approximately RM 18 through 14 July. These length and bait restrictions “follow the fish,” meaning regulations remain conservative, affording protection to both tributary- and mainstem-spawning fish upstream of RM 18 through 14 July. In addition, Chinook salmon spawning tributaries as well as sanctuary areas of the mainstem Kenai River around the confluences of Slikok Creek, Funny River, and Killey River, and the Kenai River upstream of Skilak Lake are all closed to sport fishing for Chinook salmon (Figure 1). Finally, 3 areas are closed to Chinook salmon fishing for boat anglers. The largest area is located immediately downstream of the Soldotna Bridge, with additional areas near Morgan’s Landing (just upstream of the Funny River) and near the confluence of the Moose River (Figure 1). Harvest is not completely eliminated in the boat-restricted fishing areas; for example, a successful shore fishery occurs in the boat closure area downstream of the Soldotna Bridge.

Sport fishing regulations are less conservative after 1 July; bait is allowed and length restrictions are lifted in July downstream of the Slikok Creek sanctuary. Closed and restricted fishing areas in the mainstem Kenai River remain in effect during July. The existing early- and late-run regulations previously described can be superseded by inseason emergency orders (EOs) during times of low abundance. Often, EOs are used to extend conservative regulations in upstream areas.

REPORT OBJECTIVES

Since 2010, 732 radiotagged Chinook salmon have been tracked and assigned spawning destinations from 10 different tagging events (Table 1). Most of these radio tags were deployed each year as Chinook salmon were captured during the RM 8.6 Inriver Gillnetting Project (Perschbacher 2012a, 2012b, 2014, 2015a). Radio tags were also deployed in Chinook salmon captured with gillnets at RM 21.0 during June–early July 2011–2013 and in Chinook salmon captured while trolling in Cook Inlet near Anchor Point during 2012 by ADF&G Division of Commercial Fisheries (DCF) with rod-and-reel (Reimer 2013). Inriver radiotag deployments were designed to support research objectives associated with estimating inriver abundance (Reimer et al. 2016) while marine deployments were designed to estimate saltwater migration rates and distribution. As such, the inriver migratory timing and distribution results presented in this report were generally secondary objectives during project planning. Nonetheless, this radiotelemetry study provides a vastly expanded and improved dataset of Kenai River Chinook salmon migratory timing and distribution that was analyzed with an emphasis toward supplying information relevant to fishing regulations, inseason management actions, and sonar passage estimates.

Table 1.–Number of radiotagged Kenai River Chinook salmon assigned a spawning destination by tagging event, 2010–2015.

			Number assigned a spawning destination (*N*)		
Year	Tagging location	Capture dates	Early run	Late run	Total
2010	Kenai RM 8.6	16 May–5 Jul	80	6	86
2011	Kenai RM 8.6	17 May–5 Jul	78	13	91
2011	Kenai RM 21.0	2 Jun–13 Jul	30	13	43
2012	Kenai RM 8.6	16 May–15 Aug	46	77	123
2012	Kenai RM 21.0	7 Jun–4 Jul	29	6	35
2012	Cook Inlet	14 Jul–17 Aug	–	39	39
2013	Kenai RM 8.6	16 Jun–16 Aug	37	64	101
2013	Kenai RM 21.0	30 May–27 Jun	22	–	22
2014	Kenai RM 8.6	16 May–17 Aug	94	59	153
2015	Kenai RM 8.6	16 May–27 Jun	39	–	39
Total			455	277	732

Source: 2010–2013 data from Reimer (2013).

This report presents telemetry results from 2014 and 2015 and summarizes them with results from 2010–2013 (Reimer 2013). Results are put in context with existing sport fishing regulations and historical distribution data. Objectives specific to this report are as follows:

1) Report the migratory timing and distribution by date relative to existing regulations, closed areas, and recent inseason management actions of the following Chinook salmon populations: those radiotagged during the early-run, those radiotagged during the late-run, radiotagged fish that spawned in the mainstem, and radiotagged fish that spawned in tributaries.
2) Report the estimated proportion of radiotagged Kenai River mainstem-spawning Chinook salmon that migrated upstream of RM 13.7 such that the estimate is within 8 percentage points of the true value 95% of the time for 2012–2014.
3) Estimate the Killey River Chinook salmon escapement in 2012–2015 using radiotagged Chinook salmon such that the estimate is within 30% of the true value 80% of time.

4) For radiotagged Chinook salmon that spawned in the Funny River, determine the dates when they entered the Funny River closed area and the Funny River.
5) For radiotagged Chinook salmon that spawned in the Killey River drainage, determine the dates when they entered the Killey River closed area and the Killey River.
6) Determine the dates when radiotagged Chinook salmon migrated into the Slikok Creek sanctuary in the Kenai River.
7) Determine the approximate spawning locations within the tributaries of the Kenai River via aerial surveys.
8) Determine the approximate spawning locations within the mainstem of the Kenai River.
9) Determine dates of spawning site fidelity for mainstem-spawning Kenai River Chinook salmon in 2014.

METHODS

Methods for 2014 and 2015 are reported below. Methods for earlier years are reported in Reimer (2013).

CHINOOK SALMON CAPTURE

Chinook salmon were captured and implanted with radio transmitters in the lower Kenai River near RM 8.6 in association with the annual Inriver Gillnetting Project (Perschbacher 2015b). Gillnets were 60 ft long and constructed of 5.0-inch and 7.5-inch multifiber mesh in colors that closely match Kenai River water. Gillnet web size was chosen to reduce size selectivity and to reduce the probability of damage to gill filaments during capture.

Inriver gillnetting at RM 8.6 began on 16 May each year. The ending date of tagging was variable, ending mid-August in 2014 (covering both runs) and late June in 2015 (covering most of the early run). Netting was conducted daily from 7:00 AM to 7:00 PM in 2014 and 7:00 AM to 1:00 PM in 2015. The capture area began at the RM 8.6 Chinook salmon sonar site and continued downstream for approximately 0.5 km (0.3 mi). The deployment of nets were alternated systematically with respect to bank, distance offshore (midriver or nearshore), and mesh size, and therefore 8 sets were completed in a cycle prior to repeating. Generally, 16–24 sets were conducted during each 6-hour period.

Drifts always began at the upstream end of the netting area. Drifts were terminated as follows: 1) when the net became snagged on the bottom, 2) when the net drifted outside of the intended area (midriver or nearshore), 3) when the end of the study area was reached, 4) when the predetermined maximum drift time was reached (usually 5–9 minutes depending on water flow and conditions), or 5) when generally at least 5 fish were thought to be captured in the net.

Tagging at RM 8.6

Esophageal implant pulse-coded radio transmitters were deployed into captured Chinook salmon. Tags were manufactured by Advanced Telemetry Systems[2] using up to 17 frequencies per year (151.130–151.635 MHz) and up to 25 individually identifiable tags per frequency. Two sizes of tags were used. The larger 1845B bottle-shaped radio tags were 19 mm in diameter, 56 mm long,

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

weighed 24 g, with a 12-inch antenna, and had a warranty battery life of 162 days. The smaller F1840B bottle-shaped tags were 17 mm in diameter, 56 mm long, weighed 22 grams, with a 12-inch antenna, and had a warranty battery life of 125 days.

Not every captured Chinook salmon was given a radio tag. Fish with profusely bleeding gills or observed to be lethargic were released without tagging to minimize potential differences in survival and behavior between tagged and untagged populations. Captured Chinook salmon were untangled from nets and restrained by placing a cotton "tail tie" around the caudal peduncle. Tail ties were attached to the boat gunwale using a bungee cord. This combination allowed the fish to recuperate prior to sampling and protected the fish from injury if it swam vigorously away from the boat. Tethered Chinook salmon were transferred to a padded aluminum cradle (Larson 1995) for sampling and tagging. The sampling cradle was positioned such that the fish's gills remained partially submerged while being handled.

In 2014, captured Chinook salmon were tagged regardless of size. Smaller F1840B transmitters were deployed in fish with a mid eye to tail fork (METF) length less than 600 mm and larger F1845B transmitters were deployed in fish 600 mm METF and above. Unfortunately, fish less than 495 mm METF did not survive to migrate upstream in 2014 so during 2015, only fish 500 mm METF and above were tagged. Fish less than 600 mm MEFT or longer were tagged with F1845B transmitters, and fish 500–599 mm MEFT were tagged with F1840B transmitters.

Tagging rates of the gillnetted sample of healthy fish (2014 and 2015) of appropriate size (2015) also varied within years based on both anticipated and actual catch rates in order to maintain proportional sampling throughout the run. In 2014, the entire sample was tagged during 16 May–30 June, but during 1 July–15 August, only a subsample (1 in 3) were tagged. In 2015, the entire sample was tagged during 6 May–4 June, subsampling (1 in 3 tagged) occurred during 5–22 June, and then the entire sample was tagged 23–27 June.

All radiotagged Chinook salmon were given a caudal fin "hole-punch" to prevent resampling, and were sampled for genetic tissue and age, sex, and length (ASL) information. Data were recorded electronically using data entry software on a Juniper Systems Inc. Allegro CX field computer.

Transmitters were inserted into the fish's stomach with an applicator made from 2 concentric plastic tubes. The transmitter fit snugly within the outer tube. Transmitters were inserted by gently pressing the tag against the esophageal sphincter until the sphincter relaxed, allowing the tag to pass into the stomach. The transmitter was dislodged from the applicator using the inner tube as a plunger. Glycerin was often used as a lubricant during tag applications. Every tag application was followed by a visual inspection of the esophageal sphincter. Successful applications were confirmed when the transmitter body was completely obscured by the esophageal sphincter and the antenna was directed forward out of the mouth. Unsuccessful transmitter applications were removed and repeated.

To aid tag retention, transmitters were fitted with manipulated plastic "hootchie skirts" which have been used exclusively as retention aids since 2013 due to better retention rates (Reimer 2013).

See Reimer (2013) for methods detailing Cook Inlet and RM 21 tag deployments.

RADIO TELEMETRY

Radiotagged Chinook salmon were monitored both passively, using a network of stationary radio receiving stations, and actively, by foot, boat, or aerial surveys. Stationary receiving stations allowed 24-hour monitoring of radiotagged Chinook salmon at key points along their migration routes whereas active tracking was used to determine specific locations. This system provided multiple, redundant locations for each animal with resolution sufficient to detect noteworthy behavior patterns.

Stationary Telemetry Sites

Most telemetry data were collected at automated, stationary, data-recording stations (fixed stations). Pulse-coded transmitters allowed the use of fewer frequencies and thus reduced total scan time. During stationary radiotracking, the scan time for each frequency was 7 s with a 2 s timeout. Thus, each frequency was scanned for 2 s and if a transmission was detected, then the frequency was scanned for an additional 5 s on each antenna while the equipment determined and electronically recorded the pulse code and the signal strength. If a transmission was not detected within 2 s of scanning, the equipment "timed out" on that frequency and moved to the next frequency. Given an average pulse rate of 45.8 pulses per minute, a 2 s timeout provides sufficient time for each tag to send 2 transmissions. Total scan time for all frequencies ranged from approximately 30 s, when no signals were detected, up to 7 minutes when several signals were detected. For sites where multiple, collocated, radiotagged fish were expected (such as the Killey River confluence station), 15-second scan times were used to ensure all of the radio tags present were decoded.

Each site consisted of a 3–4.5 m (10–15 ft) pole supporting a solar panel and 2 or 3 Yagi directional antennas (Cuschcraft Inc. model P154-4) connected via coaxial and communication cable to a 3 dB attenuator (Mini-Circuits, model CAT-3), antenna switch (ATS, model 200 or 300), radio receiver (ATS, model 4100, 4500 or 4520), and data collection computer (ATS, model 5041). The receiver and computer were stored in a weather-resistant box with a 12-volt marine battery. The system continuously scanned the transmitter frequencies and electronically recorded the frequency, pulse code, mortality code, date, time, antenna, and a measure of signal strength whenever a decodable transmission was detected. Sites were visited weekly to download stored data and check the system configuration.

Fixed stations were placed at key sites along Kenai River Chinook salmon migration routes (Table 2). Sites were chosen to maximize antenna height above the river surface using adjacent cut banks or bluffs whenever possible.

Table 2.–Location and purpose of fixed telemetry stations in the Kenai River drainage, 2010–2015.

Location	Kenai River RM	Years	Purpose
RM 8.6 sonar site	8.6	2010–2011	Upstream migration
RM 11.5 (Eagle Rock)	11.5	2012	DCF request
RM 13.7 sonar site	13.5	2010–2015	Mainstem migration
Slikok Creek confluence	19.0	2010–2015	Tributary use, mainstem migration
Soldotna Bridge	20.9	2010–2014	Mainstem migration
Funny River confluence	30.3	2010–2015	Tributary use, mainstem migration
Moose River confluence	36.3	2010–2014	Mainstem migration
Killey River confluence	44.3	2010–2015	Tributary use, mainstem migration
Killey River weir	–	2012–2015	% of Killey R. migrants above weir
Skilak Lake outlet	49.3	2010–2014	Mainstem migration
Skilak Lake inlet	66.2	2010–2014	Mainstem migration
Kenai Lake outlet	81.3	2010–2015	Tributary use

By orienting each site's antennas parallel to the river channel (and tributary when applicable), direction of travel could be discerned by comparing each antenna's signal strength within the chronological data. Individual fish were assigned date, time, and direction of passage for each migration past each fixed station. Passage dates and times were used to assign each fish to river sections. The river sections of interest were as follows:

1) Downstream of RM 13.7 sonar. This station was installed in order to determine migration timing between the release location at RM 8.6 and the upstream sonar and to determine the proportion of mainstem spawning occurring downstream of the RM 13.7 sonar in 2014. In 2015, tags were not deployed during the late run so it was not possible to determine the proportion of mainstem spawning occurring downstream of the RM 13.7 sonar.

2) Downstream of Slikok Creek. A large sport fishery occurs in this section. Slikok Creek approximates the boundary for restrictive Chinook salmon sport fishing regulations and is used by fishery managers to enact additional inseason protection for early-run Chinook salmon, with the waters downstream of Slikok Creek typically less affected by inseason action. There are no closed or restricted fishing areas in this section.

3) Upstream of Slikok Creek to Skilak Lake. A smaller Chinook salmon sport fishery occurs in this area. Slikok Creek approximates the boundary for more restrictive Chinook salmon sport fishing regulations and is used by fishery managers to enact additional inseason protection for early-run Chinook salmon, with the waters upstream of Slikok Creek typically restricted by inseason action. There are several closed or restricted fishing areas in this section.

4) Closed or restricted fishing areas and tributary entry. Sanctuary areas that are closed to Chinook salmon fishing exist around the confluence of Slikok Creek (400 yards in length), Funny River (1.1 miles in length), Killey River (1.75 miles in length), upstream of and including Skilak Lake, and in all tributaries to the Kenai River (Figure 1). In addition, there are sizable areas closed to boat fishing downstream of the Soldotna Bridge and upstream of Funny River (Morgan's Landing) (Figure 1). The presence or absence of

individual fish in each of these areas within a particular time was assessed using fixed station data. The number of radiotagged Chinook salmon in the Slikok Creek sanctuary and the boat-restricted area near the Soldotna Bridge was approximated by the number of radiotagged fish between RM 18.9 and 20.9 because the fixed station data alone could not locate individual fish within these areas; these radiotagged fish are reported as a group.

Active Tracking

To complement fixed-station data, radio tags were located by boat using an ATS 4520 receiver and single Yagi-style antenna (Cuschcraft Inc. model P154-4). The area between Cook Inlet and Skilak Lake was searched 2 times per week whereas the area between Skilak and Kenai lakes was searched once per week. The boat was driven at a moderate speed while scanning active frequencies for 2 seconds each. If a signal was heard, the scan was paused until the tag location could be inferred from the recorded signal strength and the antenna's direction during detection. For each radiolocated fish, the date, time, frequency, pulse code, mortality code, river mile, and coordinates (determined by a global positioning system [GPS]) were recorded using an Allegro CX field computer.

Tagged Chinook salmon were also located by airplane using an ATS 4520 receiver and 2 H-style antennas (Telonics Inc. model RA-2AK) attached to the strut for each wing. When the plane flew level to the ground, the antennas were pointed approximately 45 degrees to the ground surface. Signals could be monitored from each individual antenna or both antennas together using an ATS Inc. manual antenna switch box. Both antennas were monitored while flying except when attempting to discern direction. The plane typically flew 600–1000 ft above the ground surface at approximately 80 mph. The plane was positioned to the side of the river to maintain line of sight with the water. The Funny and Killey rivers plus the tributaries upstream of Skilak Lake were searched approximately every 10 days between late June and mid-August. Each frequency was scanned for 2 seconds. If a signal was heard, the scan was paused briefly while the receiver decoded the tag and recorded the signal strength, date, time, frequency, pulse code, mortality code, and GPS coordinates. This process was repeated each time a transmission was heard. The record with the largest signal strength was assumed to best describe the tag position. A secondary paper matrix was used to back up the electronic record and verify adequate detection.

When possible in select tributaries, radio tags were also located by foot using an ATS 4520 receiver and a handheld H-style antenna (Telonics Inc. model RA-23K). Each frequency was scanned for 2 seconds. If a signal was heard, the scan was paused until the tag location could be inferred from the recorded signal strength and the antenna's direction during detection. For each radiolocated fish, the date, time, frequency, pulse code, mortality code, and GPS coordinates were recorded electronically by the receiver.

DETERMINATION OF FATE

In 2014, radiotagged fish were assigned 1 of 4 fates based on their behavior post-tagging: dropout, regurgitation, censor, or migrant. All of the telemetry data were consolidated into 1 graphic per fish before deciding on a fate. Dropouts, regurgitations, and censors are similar in their failure to provide useful spawning destination or migratory timing information.

1) <u>Dropouts:</u> Fish categorized as dropouts probably entered salt water immediately after tagging. Because radio tags cannot transmit a signal through salt water, dropouts were rarely located after being deployed. Some of these fish were direct handling mortalities,

although commercial harvest of tagged fish and relocation of tagged fish reentering the Kenai River after a post-tagging absence indicate that some estuarine and salt water milling occurred after tagging without handling-induced mortality.

2) Regurgitation: Tags that were permanently stationary immediately after deployment and were proximate to or downstream of the tagging site were categorized as regurgitations. Regurgitated tags were presumed ejected from the esophagus and are distinguishable from mortalities because dead radiotagged fish are often characterized by rapid downstream movement. Because radio tags were deployed in the tidally influenced zone, some fish classified as regurgitations could have been dropouts that were not flushed out to salt water due to a lack of current. This error would have little influence on our primary results because neither fate was used in the spawning destination analysis or migratory timing analysis. Permanently stationary tags upstream of the tagging site were very rare, indicating regurgitation upstream of the tagging site is very rare, especially because some instances of permanently stationary tags upstream of the tagging site clearly resulted from harvest.

3) Censor: Fish that displayed post-tagging upstream migration that was insufficient in length, distance, or duration, and could not be placed in a spawning area during a spawning period for a period of time sufficient for spawning, were censored from the analysis. Criteria for classifying censored fish are explained in detail below.

4) Migrant: Fish that migrated upstream of the tagging site and entered known spawning areas during known spawning periods for a period of time sufficient for spawning were considered migrants. Chinook salmon that entered a Kenai River tributary were considered migrants to that tributary. Tributary use was verified by both station and aerial tracking data in most cases. A few instances occurred where tributary use was definitively indicated by station data but not verified by aerial tracking data. Mainstem Kenai River spawning Chinook salmon were assigned a spawning destination based on demonstrated site fidelity.

In 2015, fish were classified as either censors or migrants due to the limited amount of data collected and because there were only fixed-station and aerial telemetry data that could be used to analyze migration.

Censoring Criteria for Fish in the Mainstem Kenai River

The most difficult process in determining the fate of radiotagged fish was discriminating between fish that failed to spawn and should be censored from further analysis from fish that should be considered migrants that spawned in the mainstem of the Kenai River. Migrating Chinook salmon often hold in the mainstem of the Kenai River for days or weeks prior to resuming upstream migration. However, most of the Kenai River provides suitable spawning substrate, and spawning and migrating fish are indistinguishable while co-located. Holding behavior is often revealed by subsequent upstream migration. When holding behavior was followed by mortality, fish were censored because they failed to meet the following minimum spawning requirements. These criteria were applied sequentially, although many fish would have been censored by several criteria:

1) Fish that were harvested could not have spawned.

2) Fish that failed to display site fidelity upstream of RM 12.8 could not have spawned [3].
3) Fish deemed mortalities prior to 1 July could not have spawned.
4) Fish that failed to display 6 days of site fidelity prior to mortality could not have spawned.
5) Fish deemed mortalities within 18 days of release could not have spawned.

Previous authors (Bendock and Alexandersdottir 1990-1992) have identified RM 12 as the downstream limit to Chinook salmon spawning. In 2009, ADF&G staff used drift gillnets to capture mainstem spawning Chinook salmon in the lower Kenai River for genetic baseline sampling, but were unable to locate spawning Chinook salmon downstream of RM 13.0 (Honeymoon Cove). We used RM 12.8 in this report as the downstream limit of Chinook salmon spawning because a couple fish appeared to have spawned near RM 12.8. There is no difference in using RM 12.8 versus RM 12 because the few fish that migrated upstream of RM 12 but failed to migrate upstream of RM 12.8 were censored by other criteria.

Side fidelity was measured as the date when a radiotagged Chinook salmon showed fidelity to its eventual spawning area. Site fidelity dates are not intended to approximate active spawning, but rather to provide an early bound on the date when spawning may have begun. ADF&G staff used drift gillnets to capture mainstem spawning Chinook salmon in various river sections during August and September of 2003, 2006, 2009, and 2011. For all years and sampling events, most Chinook salmon captured in mid-August were firm and did not express gametes in response to light abdominal pressure, but the majority of the Chinook salmon captured by the end of August were ripe and expressed gametes with light abdominal pressure. Based on these observations, we used the minimum values for site fidelity and stream life displayed by fish spawning in September to approximate the minimum values of fish that spawned earlier in the season. This method should be conservative because stream life is known to decrease for the latest arriving salmon (Quinn 2005).

Mortality Criteria

Most of the censoring criteria require assigning a mortality date to radiotagged Chinook salmon. Two complementary sources of information were used to determine mortality: 1) rapid, permanent, downstream movement, and 2) the radio tag's mortality signal. Downstream movement was detected by boat and airplane tracking and by sequential records on downstream fixed stations. The radio tag mortality signal was activated after 18 hours without detectable movement. Permanent downstream movement was a definitive indicator of mortality in that it either resulted in the radio tag being flushed into Cook Inlet or was followed by mortality signals if the radio tag remained in fresh water. Mortality signals alone were less definitive because radio tags in obviously live fish can emit a mortality signal and conversely, radio tags in obviously dead fish can fail to emit a mortality signal. Therefore, mortality signals were considered in aggregate and fish were deemed mortalities only after consistent mortality signals were detected for the remaining tracking events. When inconsistent mortality signals were detected, a mortality date was not assigned.

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[3] The censoring criterion based on site fidelity location is different than that used in Reimer (2013). In 2014, 2 fish were determined to have spawned near RM 12.8 so the censoring criterion based on river mile was altered to RM 12.8. Using the new criteria on the 2010–2013 data would not have changed the fate assignment for any fish.

In some situations, tagged Chinook salmon were proximate to a fixed station prior to mortality and the mortality date could be determined in daily resolution. When a mortality occurred out of range of a fixed station, the midpoint between the last live track and the first indication of mortality was used as the mortality date. This system worked particularly well in the mainstem Kenai River because voluminous manual and stationary tracking data were available. The rare occasions when mortalities could not be assigned to radiotagged fish within the mainstem Kenai River were usually associated with late arriving fish that were still alive during the last tracking event of the season.

Tributary-spawning Chinook salmon were assigned mortality dates less often and less precisely due to the lack of fixed stations within tributaries and the resulting paucity of telemetry data available while the fish was in the tributary.

Spawning Destinations

For data collected in 2010–2013, Reimer (2013) determined the mainstem spawning destinations as the last observed location within the site fidelity window. In this report, the locations within the site fidelity window were analyzed with more time and resolution to better determine the most likely spawning location. Data for all radiotagged mainstem-spawning Chinook salmon during 2010–2015 were analyzed with this higher resolution and therefore spawning destinations from all mainstem-spawning Chinook salmon radiotagged between 2010 and 2013 in this report supersede the mainstem spawning destinations reported in Reimer (2013). In the analysis presented here, there were 339 spawning destinations analyzed from 2010–2014. The last location within the site fidelity window was used as the spawning destination in 207 (61%) of fish. In 31 of those 207 fish (15%), the last location within the site fidelity window was also the most upstream location. The second to last location was used as the spawning destination in 58 (17%) of fish, the most upstream location was used as the spawning destination in 41 fish (12%). The remaining 10% of spawning destinations were chosen as either the median date within the site fidelity window, the center location within a close group of locations, or in a few cases, the project biologist used professional judgement in choosing the mostly likely spawning location from the boat tracking locations within the site fidelity window. When the 2010–2013 mainstem spawning data were reanalyzed, over half of the spawning destinations remained unchanged and most changes that occurred were minor; however, there were several cases in which the spawning destination changed by 0.5 RM or more.

Spawning destinations for tributary spawners were determined via aerial surveys and were the most upstream location observed.

TEMPORAL WEIGHTING

The spawning destinations assigned to radiotagged Chinook salmon were used to estimate composition (tributary spawners or mainstem spawners) of Chinook salmon subjected to the Kenai River sport fishery upstream and downstream of Slikok Creek sanctuary as well as to determine the locations of various stocks or run timing groups relative to regulatory boundaries throughout their instream migration. However, the fraction of captured Chinook salmon that were radiotagged ("tagging rate") varied by each run and year. For weighting conducted in 2010–2013, see Reimer (2013). In 2014, every healthy Chinook salmon that was sampled by gillnet was tagged during 16 May–30 June and every third captured fish (a subsample) was tagged 1 July–15 August. In 2015, all Chinook salmon of the appropriate size and vitality were tagged during 16 May–3 June and 23–27 June. During 4–22 June, every third Chinook salmon was tagged.

To account for the different tagging rates within each year, we split 2014 into 2 time strata (16 May–30 June and 1 July–15 August) and 2015 into 3 time strata (16 May–4 June, 5–22 June, and 23–27 June). We then assigned weights (w_i) to each time stratum inversely proportional to the tagging rate for that stratum:

$$w_i = \frac{c_i}{t_i} \tag{3}$$

where c_i is the number of Chinook salmon caught by the midriver crew during time stratum *i*, and t_i is the number of fish tagged by the midriver crew during stratum *i*.

Then p_s, the contribution of stock *s* can be estimated as follows:

$$\hat{p}_s = \frac{\sum_{i=1}^{T} w_i n_i}{\sum_{i=1}^{T} w_i m_i} \tag{4}$$

where n_i is the number of fish from stock *s* (group of interest, e.g., mainstem) tagged during time stratum *i* that were found in a specific section of the river, m_i is the total number of fish tagged during time stratum *i* that were found in a specific section of the river, and *T* is the number of time strata.

Assuming independence of the tagging events in different time strata and treating m_i as a constant, the variance of $\hat{p}_s$ can be estimated as follows:

$$\text{var}(\hat{p}_s) = \frac{\sum_{i=1}^{T} w_i^2 \,\text{var}(n_i)}{(\sum_{i=1}^{T} w_i m_i)^2} \tag{5}$$

where

$$\text{var}(n_i) = m_i \hat{p}_i (1 - \hat{p}_i) \tag{6}$$

and

$$\hat{p}_i = \frac{n_i}{m_i}. \tag{7}$$

KILLEY RIVER ESCAPEMENT

The USFWS operated a weir on the Killey River from 2012 to 2015; however, escapement must be estimated for these years because many fish spawn below the weir. The proportion of radiotagged salmon that migrated above the weir and weir passage estimates were used to estimate escapements for 2012–2015. Killey River escapement was estimated for 2012–2014 (excepting 2015) using the Chapman estimator, in the following form:

$$\hat{N} = \frac{(m+1)(N_{weir}+1)}{n+1} - 1 \tag{8}$$

with variance estimated as

$$\text{var}(\hat{N}) = \frac{(m+1)(N_{weir}+1)(m-n)(N_{wier}-n)}{(n+1)^2(n+2)} \tag{9}$$

in which m denotes the number of marked fish entering the Killey River, n denotes the number of marked fish observed at the Killey River weir, and N_{weir} denotes the total weir passage.

Tag deployments at RM 21.0 were included to estimate Killey River escapement in 2012 and 2013 to increase sample size and because the observed proportion $\hat{p}$ of Killey River Chinook salmon above the Killey River weir was not significantly different between the RM 8.6 and RM 21.0 samples.

Killey River abundance was estimated differently for 2015 than for 2012–2014 because tagging rates varied over time during the 2015 early run, but were constant over the run for 2012–2014. For 2015, the proportion of Chinook salmon spawning above the Killey River weir was estimated by incorporating tagging weights using Equation 4 with variance estimated using Equation 5, with n_i denoting the number of tagged Chinook salmon recorded at the weir belonging to tagging stratum i, m_i denoting the number of tagged Chinook salmon entering the Killey River belonging to tagging stratum i, and w_i denoting the sampling weight of each stratum calculated using Equation 3, with c_i denoting the number of Chinook salmon caught in time stratum i and t_i denoting the number of Chinook salmon caught and tagged from time stratum i.

The inverse of the proportion of Chinook salmon spawning above the Killey River weir was used to construct an estimator of Killey River escapement, in the following form:

$$\hat{N} = \frac{N_{weir}}{\hat{p}} \tag{10}$$

The variance of this estimator was estimated as the following:

$$\text{var}(\hat{N}) = N_{weir}^2 \text{ var}\left(\frac{1}{\hat{p}}\right) \tag{11}$$

with $\text{var}\left(\frac{1}{\hat{p}}\right)$ approximated, according to the delta method (Casella and Berger 2002), as:

$$\text{var}\left(\frac{1}{\hat{p}}\right) = \frac{\text{var}(\hat{p})}{\hat{p}^4} \tag{12}$$

Because $\hat{p}$ was estimated by incorporating tagging weights, its variance $\text{var}(\hat{p})$ was estimated as follows, again with n_i, m_i, and w_i respectively denoting the number of tagged Chinook salmon at the weir, entering the Killey River, and respective sampling weight, for stratum i:

$$\text{var}(\hat{p}) = \frac{\sum_{i=1}^{k} w_i^2 \, \text{var}(n_i)}{\left(\sum_{i=1}^{k} w_i m_i\right)^2} \tag{13}$$

where

$$\text{var}(n_i) = m_i \hat{p}_i (1 - \hat{p}_i) \tag{14}$$

and

$$\hat{p}_i = \frac{n_i}{m_i}. \tag{15}$$

The delta method was used again to estimate the bias of $\frac{1}{\hat{p}}$, thus allowing the modification of Equation 10 to construct an approximately unbiased estimator for abundance as follows:

$$\hat{N}_{unb} = N_{weir}\left(\frac{1}{\hat{p}} - \frac{\text{var}(\hat{p})}{\hat{p}^3}\right). \tag{16}$$

Thus, Equation 16 was used to estimate Killey River abundance in 2015, and Equations 11–15 were used to estimate its variance.

COMPOSITION BY MANAGEMENT AREA

The proportional composition of Chinook salmon exposed to sport fisheries within the Kenai River is presented as an approximation of the fish available for harvest relative to entry timing and spawning destination. Because sport-caught Chinook salmon may be released based on size, sex, coloration, maturity, regulations, or other factors, the estimated composition of fish available for harvest may differ from the composition of the actual harvest because of harvest decisions made by individual anglers.

Kenai River Chinook salmon fishery management differs by year, time of year, and river section. We use Slikok Creek (RM 19) to separate the Kenai River sport fishery into 2 areas. For the Kenai River upstream of Slikok Creek, fixed telemetry stations were used to exclude fish located within the areas closed to fishing around the confluences of Slikok Creek, Funny River, Killey River, the area upstream of Skilak Lake, and the areas restricted to shore fishing near Centennial Park and upstream of Funny River (Morgan’s Landing). Radio tags were not deployed in the late run in 2015, so data from 2015 are excluded. Radiotagged Kenai River Chinook salmon located within these areas were divided into tributary and mainstem based on assigned spawning destination.

The proportions of Chinook salmon between management areas were estimated and smoothed using a binomial Generalized Additive Model (GAM) (Wood 2011) of the form below in which

Y_i, the presence of fish *i* in a given management area, is assumed to be Bernoulli-distributed with probability parameter π_i and $s(Date_i)$ denotes a spline basis defined by a piecewise polynomial function.

$$Y_i \sim Bern(\pi_i) \tag{17}$$

and

$$\ln\left(\frac{\pi_i}{1-\pi_i}\right) = s(Date_i) \text{ or}$$
$$\pi_i = \frac{\exp(s(Date_i))}{1+\exp(s(Date_i))}. \tag{18}$$

Management areas included in the analysis were RM 0–19, RM 19–50, and the closed or restricted areas in RMs 19–50.

RESULTS

TAG DEPLOYMENTS AND FATES

2014

Chinook salmon were captured and tagged from 16 May through 15 August. In the early run, all captured Chinook salmon deemed healthy were tagged, and during the late run, approximately every third healthy Chinook salmon was tagged. Tags were deployed in 159 Chinook salmon during the early run. Of those, 128 (81%) were Chinook salmon captured midriver and 31 (19%) were captured nearshore (Table 3). During the late run, 117 tags were deployed: 100 (86%) were captured midriver and 17 (14%) were captured nearshore. Of all the Chinook salmon tagged in 2014, 55% (153) were classified as migrants and assigned a spawning destination. The remaining 123 tags were split between 23 drop-outs (8%), 35 regurgitations (13%), and 65 censors (24%). Of censored fish, the majority did not meet site fidelity or river mile criteria (Table 4).

In 2014, Chinook salmon were tagged regardless of size. Although smaller Chinook salmon were tagged with smaller tags, only 1 of the 18 tagged Chinook salmon less than 500 mm METF was classified as a migrant, and that fish was 495 mm METF in length. In contrast, Chinook salmon of other size classes were classified as migrants in approximately the same proportions as they were tagged (Figure 2). Consequently, the minimum length for tagging in 2015 was set at 500 mm METF.

2015

Tags were deployed from 16 May through 27 June. All healthy Chinook salmon that met the tagging criterion (greater than or equal to 500 mm METF) were tagged during 16 May–4 June and 23–27 June. The tag deployment rate was decreased to 1 in every 3 fish between 5–22 June. A total of 77 tags were deployed during the early run in 2015 (Table 5). Tags were deployed in 57 (74%) Chinook salmon captured midriver and 20 (26%) captured nearshore. Of radiotagged salmon, 42 (55%) fish were deemed migrants, and 35 (45%) fish were censored.

Table 3.–Fate by tagging event of Kenai River Chinook salmon radiotagged at RM 8.6 in 2014.

		Midriver		Nearshore		Total	
Run	Fate	N	%	N	%	N	%
Early run							
	Drop-out	6	5	3	10	9	6
	Regurgitate	19	15	6	19	25	16
	Censor	25	20	6	19	31	19
	Migrant	78	61	16	52	94	59
	Total	128		31		159	
Late run							
	Drop-out	10	10	4	24	14	12
	Regurgitate	8	8	2	12	10	9
	Censor	29	29	5	29	34	29
	Migrant	53	53	6	35	59	50
	Total	100		17		117	
Totals							
	Drop-out	16	7	7	15	23	8
	Regurgitate	27	12	8	17	35	13
	Censor	54	24	11	23	65	24
	Migrant	131	57	22	46	153	55
	Grand total	228		48		276	

Table 4.–Censoring criteria by tagging event for Kenai River Chinook salmon radiotagged at RM 8.6 in 2014.

	Midriver		Nearshore	
Censor criteria	N	%	N	%
Harvest	2	4	0	0
Date	8	15	5	45
Rivermile	12	22	1	9
Site fidelity	28	52	4	36
Stream life	4	7	1	9
Grand total	54		11	

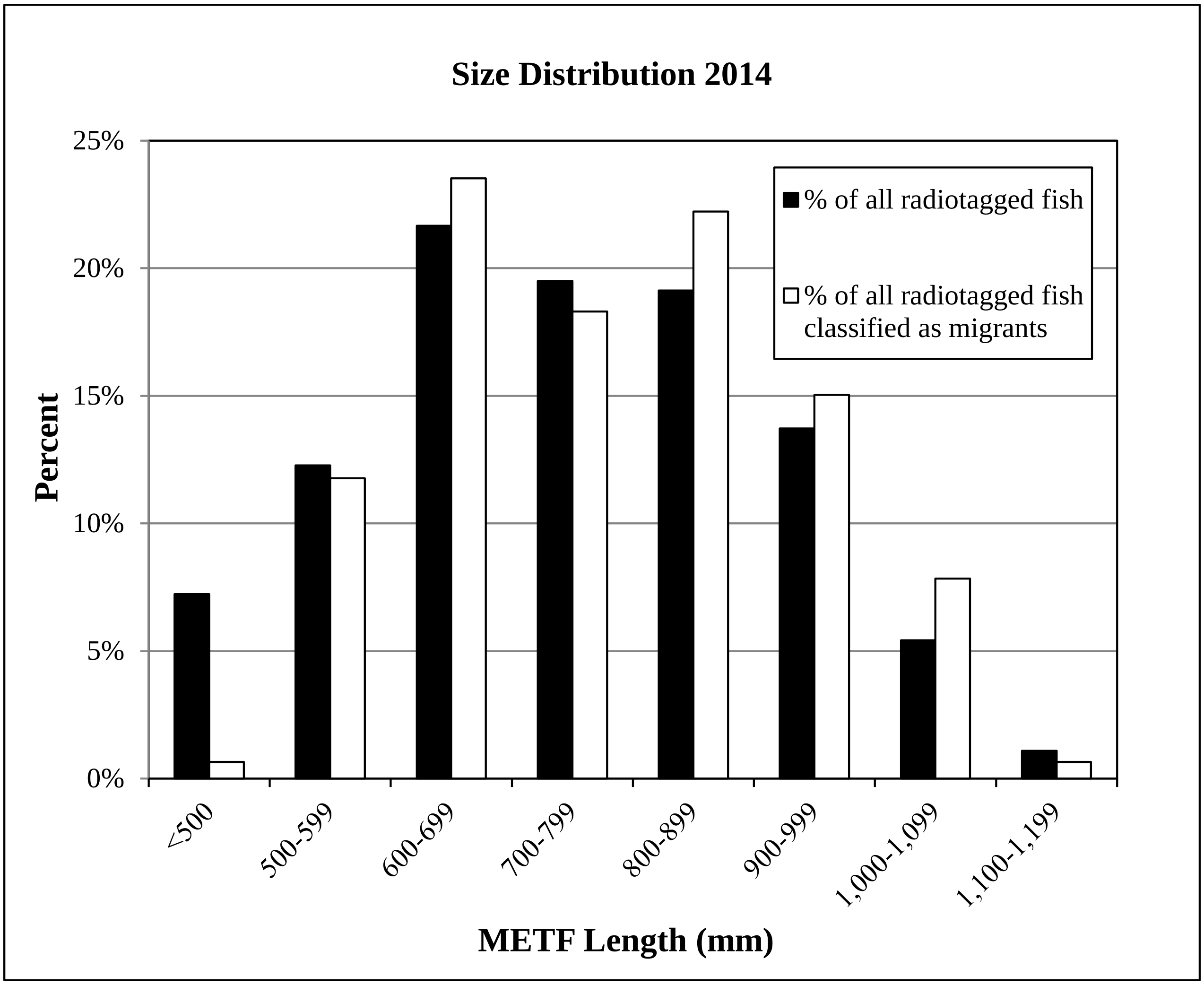

Figure 2.–Size distribution of Kenai River Chinook salmon that were radiotagged vs. size distribution of all radiotagged fish that were classified as migrants, 2014.

Table 5.–Fate by tagging event of Kenai River Chinook salmon radiotagged at RM 8.6 in 2015.

	Midriver		Nearshore		Total	
Fate	N	%	N	%	N	%
Migrant	31	54	11	55	42	55
Censor	26	31	9	31	35	45
Total	57		20		77	

SPAWNING DESTINATIONS

2014 Distribution

Early-run Chinook salmon tagged during 2014 were assigned spawning destinations primarily in the Killey River (32%, SE 5%) and Benjamin Creek (22%, SE 4%), followed by Funny River (20%, SE 4%) and mainstem Kenai River (19%, SE 4%) (Table 6).

Mainstem-spawning Chinook salmon that returned during the early run were assigned spawning destinations throughout all river sections, with most occurring downstream of the Soldotna Bridge (RM 10–21; 7%, SE 3%) followed by the area between Moose River confluence and Skilak Lake (RM 36.3–50; 5%, SE 2%) (Table 6).

During the late run, Chinook salmon were assigned spawning destinations throughout the mainstem of the Kenai River. Moose River to Skilak Lake outlet (RM 36.3–50) had the highest percentage of assigned spawning destinations (40%, SE 6%), followed by downstream of Soldotna Bridge (RM 10–21; 38%, 6%), and Soldotna Bridge to Moose River (RM 21–36.3; 12% SE 4%) (Table 7). All but 1 late-run Chinook salmon tagged during 2014 was assigned a spawning destination in the mainstem Kenai River; the tributary bound fish was tagged on 4 July and migrated to Quartz Creek.

2015 Distribution

Early-run Chinook salmon tagged during 2015 were assigned spawning destinations in Benjamin Creek (38%, SE 8%), Killey River (33%, 8%), Funny River (18%, 6%), mainstem Kenai River (5%, SE 4%), Russian River (3%, SE 3%), and Juneau Creek (3%, SE 3%) (Table 6). Although tributary-spawning Chinook salmon accounted for 95% (SE 4%) of spawning destinations and Kenai River mainstem spawners accounted for the remaining 5% (SE 4%) of spawning destinations, these spawning destination percentages do not represent the entire early run because tags were only deployed through 27 June and tagged fish were not regularly tracked in the mainstem Kenai River like they were in previous years. Consequently, the fate determinations for mainstem spawning fish are considered to represent minimum estimates.

Table 6.–Spawning distributions determined for early-run Kenai River Chinook salmon radiotagged near rivermile 8.6, 2014–2015.

		2014						2015[a]					
		Midriver		Nearshore		Combined		Midriver		Nearshore		Combined	
Location		N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)
Tributary													
	Slikok C.												
	Funny R.	15	19 (4)	4	25 (11)	19	20 (4)	6	21 (8)	1	10 (9)	7	18 (6)
	Killey R.	26	33 (5)	4	25 (11)	30	32 (5)	10	34 (9)	3	30 (14)	13	33 (8)
	Benjamin C.	18	23 (5)	3	19 (10)	21	22 (4)	11	38 (9)	4	40 (15)	15	38 (8)
	Russian R.	2	3 (2)	1	6 (6)	3	3 (2)	1	3 (0)			1	3 (3)
	Juneau C.	2	3 (2)			2	2 (1)	1	3 (3)			1	3 (3)
	Quartz C.												
	Crescent C.												
	Daves C.												
	Trail River	1	1 (1)			1	1 (1)						
	Grant Creek												
	Tributary sum	64	82 (4)	12	75 (11)	76	81 (4)	29	44 (9)	8	18 (12)	37	95 (4)
Mainstem[b]													
	RM 0–21	6	8 (3)	1	6 (6)	7	7 (3)			2	20 (13)	2	5 (4)
	RM 21–36.3	2	3 (2)	1	6 (6)	3	3 (2)						
	RM 36.3–50	3	4 (2)	2	13 (8)	5	5 (2)						
	RM 50–65	1	1 (1)			1	1 (1)						
	RM 65–82	2	3 (2)			2	2 (1)						
	Mainstem sum	14	18 (4)	4	25 (11)	18	19 (4)	0	0 (0)	2	20 (13)	2	5 (4)

[a] Radio tags were deployed 16 May-27 June and fail to span the entire early run.

[b] The Kenai River mainstem is divided into the following sections: downstream of Soldotna Bridge (RM 0–21), Soldotna Bridge to Moose River (RM 21–36.3), Moose River confluence to Skilak Lake outlet (36.3–50), Skilak Lake (50–65), Skilak Lake to Kenai Lake (65–82).

Table 7.–Spawning distributions determined for late-run Kenai River Chinook salmon radiotagged near rivermile 8.6, 2014.

Location		Midriver [a]		Nearshore [b]		Combined [b]	
		N	% (SE%)	N	% (SE%)	N	% (SE%)
Tributary							
	Quartz C.	1				1	100 (0)
	Tributary sum	1	2 (2)			1	2 (2)
Mainstem							
	RM 0–21	20	38 (7)	2	40 (22)	22	38 (6)
	RM 21–36.3	7	13 (5)			7	12 (4)
	RM 36.3–50	21	40 (7)	2	40 (22)	23	40 (6)
	RM 50–65						
	RM 65–82	5	9 (4)	1	20 (18)	6	10 (4)
	Mainstem sum	53	98 (2)	5	100 (0)	58	98 (2)

Within-Tributary Spawning Distribution

Spawning distributions within the Funny and Killey river drainages were approximated as the most upstream location recorded via aerial tracking. Because tracking flights were infrequent (every 10–20 days), it’s likely that some fish traveled farther upstream than recorded. Coordinates (tag locations) were recorded at the location where the strongest signal was received, which was generally offset from the river because the plane did not fly directly over the river in order to maintain visual line of sight of the river. On some occasions, particularly near Benjamin Creek, the strongest signal (and recorded coordinates) was away from the anadromous stream because the plane was circling over a small area where fish were densely concentrated. In many cases, these types of locations were moved to the nearest location within the survey stream. Putative Funny River and Killey River spawning distributions in 2014 and 2015 are shown in Figure 3, and distributions for all tagging years combined (2010–2015) are shown in Figure 4.

Funny River

Radiotagged Chinook salmon were distributed throughout the lower two-thirds of the Funny River drainage (Figures 3 and 4). The downstream reaches of the Funny River are road accessible and have been visually confirmed as spawning areas. The USFWS weir was located low in the drainage, although some Chinook salmon spawned downstream of the weir location. For example, Reimer (2013) visually confirmed a single radiotagged Chinook salmon that probably spawned downstream of the weir in 2013 and another radiotagged fish was suspected to have spawned downstream of the weir in 2010. In 2014, it is likely that 1 radiotagged fish also spawned downstream of the weir, although it was not visually confirmed and aerial locations were not precise enough to be conclusive. For all years combined, 49 radiotagged fish conclusively migrated upstream of the Funny River weir, 1 fish probably spawned downstream of the weir, and 2 fish were near the weir but their exact location relative to the weir was not visually confirmed. Based on these results, the Funny River weir passage provided by USFWS should be a near census of Funny River Chinook salmon spawning escapement.

Killey River

Chinook salmon were distributed throughout most reaches of the Killey River (Figures 3 and 4). The Killey River is murky during the summer glacial melt and spawning activity has not been visually confirmed in the lower sections of the Killey River. Dense concentrations of Chinook salmon were present in the lower reaches of Benjamin Creek and in the Killey River near the confluence with Benjamin Creek. Benjamin Creek is a well-known spawning area where spawning has been visually confirmed and spawning fish have been sampled on multiple occasions.

The location of the Killey River weir is such that Chinook salmon spawning in Benjamin Creek must pass the weir, but not all of Killey River spawners pass the weir. A fixed telemetry station was installed near the Killey River mouth during each year and also at the Killey River weir to determine the number of radiotagged Chinook salmon that migrated into the Killey River and the number of tagged fish that migrated upstream of the weir. Aerial surveys and boat surveys by USFWS weir crews provided more refined distribution data that was compared to the fixed station data to verify tagged fish passage at each location (Killey River mouth and Killey River weir) and to determine if fish upstream of the Killey River weir migrated into Benjamin Creek.

Table 8 provides a summary of radiotag distributions within the Killey River drainage relative to the weir and Benjamin Creek for 2012–2015. The percentage of radiotagged Chinook salmon that migrated upstream of the weir (including Benjamin Creek) in 2014 was similar to 2012 and 2013, but was higher in 2015. The percentage of tags upstream of the weir ranged from 40% (SE 7%) in 2012 to 64% (SE 9%) in 2015 (Table 8) and averaged 50% (SE 4%) for all 4 years.

Killey River Escapement

Since 2012, ADF&G has been tasked with determining the radiotag distribution within the Killey River drainage in relation to the weir, while the USFWS has installed and operated the Killey River weir and provided weir passage estimates. Estimates of escapement presented here were derived using a simpler model that uses the proportion of Killey River radio tags that pass the Killey River weir to the total Killey River weir passage. Although weir passage has ranged from 1,602 in 2012 to 2,653 in 2015, the Killey River escapement estimates have only varied from 3,564 (SE 500) in 2015 to 3,934 (SE 627) in 2012 (Table 9).

To investigate size bias in radiotagged Chinook salmon passing the Killey River weir, the cumulative length distribution of radiotagged Chinook salmon that migrated upstream the Killey River weir was compared to the cumulative length distribution of radiotagged Chinook salmon that remained downstream of the Killey River weir (Table 10 and Figure 5). There was no significant difference in the cumulative length distributions between each sample in any year (Table 10).

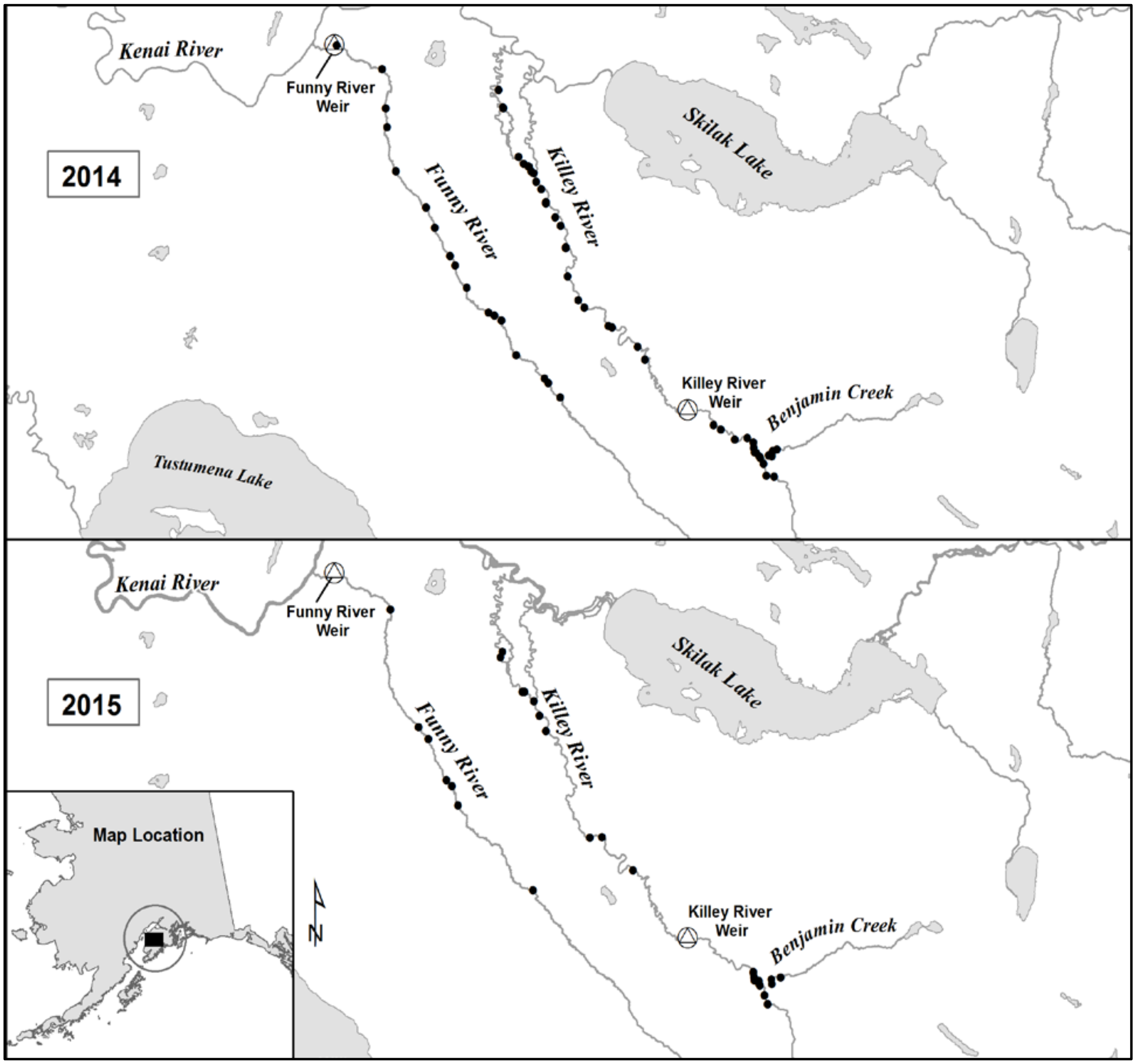

Figure 3.–Farthest upstream aerial locations for radiotagged Chinook salmon in 2014 (top) and 2015 (bottom) within the Funny River and Killey River drainages.

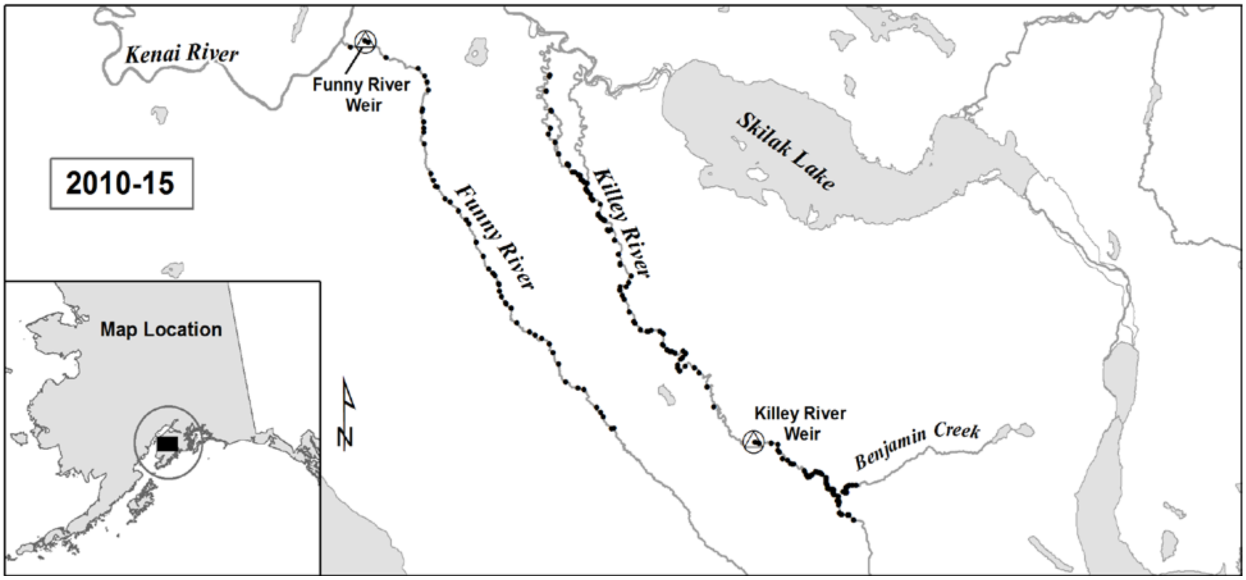

Figure 4.–Farthest upstream aerial locations for radiotagged Chinook salmon within the Funny River and Killey River drainages, 2010–2015.

Table 8.–Distributions relative to the Killey River weir of radiotagged Chinook salmon located within the Killey River drainage, 2012–2015.

	Downstream of Killey River weir		Upstream of Killey River weir (excluding Benjamin Creek)		Benjamin Creek		Total of upstream of Killey River weir and Benjamin Creek	
Year	N	% (SE%)	N	% (SE%)	No.	% (SE%)	N	% (SE%)
2012[a]	32	60 (7)	4	8 (4)	17	32 (6)	21	40 (7)
2013[a]	19	50 (8)	3	8 (4)	16	42 (8)	19	50 (8)
2014	27	53 (7)	3	6 (3)	21	41 (7)	24	47 (7)
2015	10	36 (9)	3	11 (6)	15	54 (9)	18	64 (9)
Average (%)		50 (4)		8 (2)		42 (4)		50 (4)

[a] Radio tags were deployed at RM 8.6 and RM 21.

Table 9.–Killey River Chinook salmon weir passage and escapement estimates, 2012–2015.

Year	Number downstream of weir (SE)	Weir passage [a]	Escapement (SE)
2012	2,332 (627)	1,602	3,934 (627)
2013	1,788 (556)	1,881	3,669 (556)
2014	1,851 (500)	1,713	3,564 (500)
2015	997 (412)	2,653	3,650 (412)

[a] Source: Gates and Boersma (2013, 2014a, 2014b, 2016).

Table 10.–Komolgrov–Smirnov (KS) test results for the cumulative length distribution of radiotagged Chinook salmon that migrated upstream or remained downstream of the Killey River weir, 2012–2015.

Year	Downstream of weir (*n*)	Upstream of weir (*n*)	Perm *P*-value [a]	KS D-statistic	KS *P*-value
2012	32	21	0.93	0.20	0.72
2013	19	19	0.37	0.26	0.53
2014	27	24	0.36	0.21	0.61
2015	10	18	0.91	0.24	0.84

[a] A permutation test of the difference in means was performed each year.

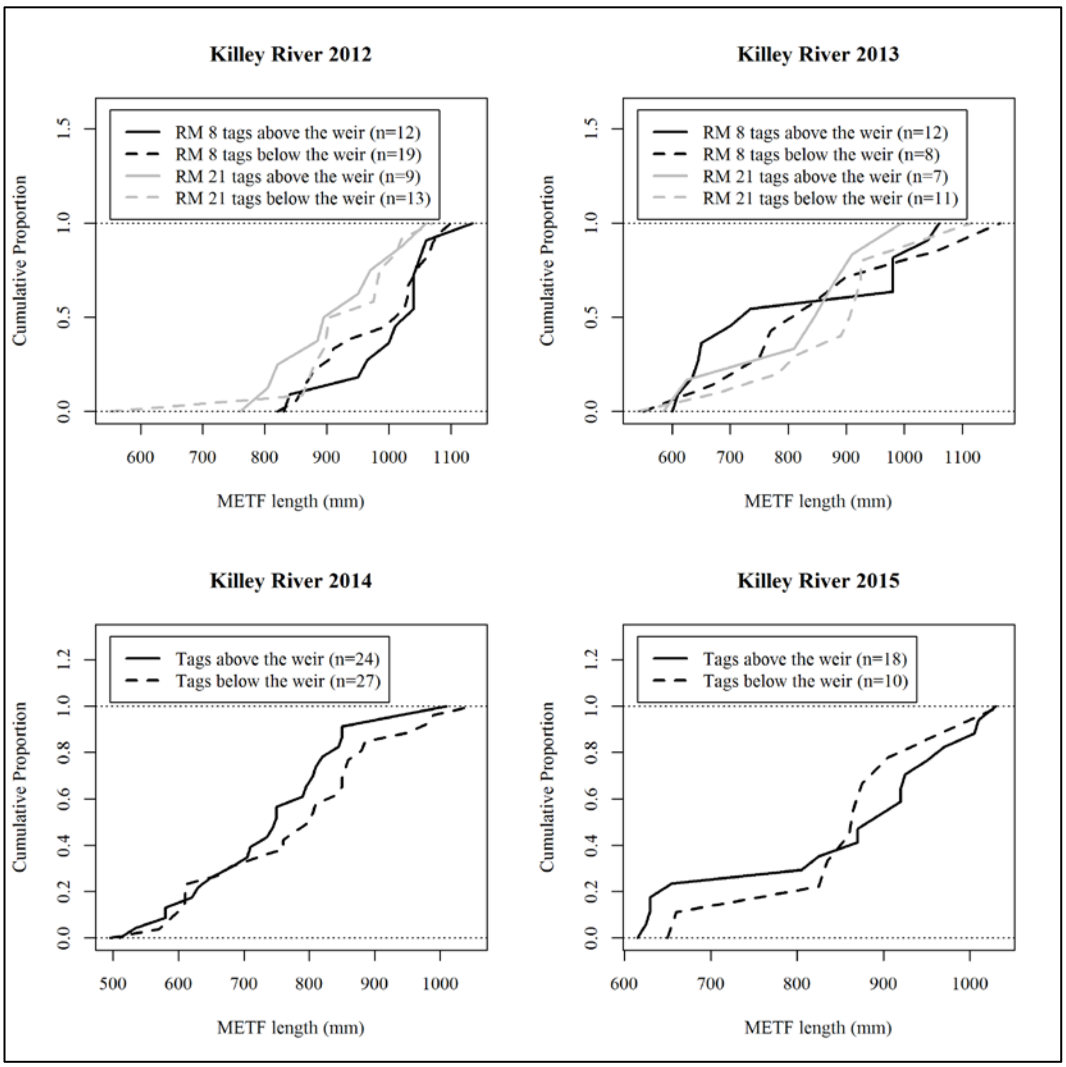

Figure 5.–Cumulative length distributions compared for Killey River Chinook salmon radiotagged at Kenai RM 8.6 that migrated upstream of the Killey River weir or remained downstream of the Killey River weir, 2012–2015.

Bias in Estimates of Tributary Spawning Destinations

Cumulative length distributions were compared for radiotagged Chinook salmon that passed the Funny and Killey River weirs and weir samples for the Funny River (Figure 6) and the Killey River (Figure 7). The length distributions of radiotagged fish that passed each tributary weir were significantly larger than the length distributions of all fish that passed each tributary weir in 5 of the 10 comparisons we made (Table 11).

Table 11.–Komolgrov–Smirnov (KS) test results for the cumulative length distributions of radiotagged Chinook salmon that passed the Funny River and Killey River weirs compared to Chinook salmon sampled at weirs.

Tributary	Year	Weir length samples (*N*)	Radiotagged fish length samples (*N*)	Perm *P*-value [a]	KS D-statistic	KS *P*-value
Killey River	2012	357	21	0.00	0.50	0.00
	2013	661	19	0.00	0.48	0.00
	2014	556	24	0.18	0.20	0.33
	2015	863	18	0.00	0.39	0.01
Funny River	2010	268	10	0.32	0.25	0.58
	2011	201	15	0.00	0.50	0.00
	2012	181	8	0.00	0.79	0.00
	2013	217	7	0.08	0.45	0.13
	2014	381	19	0.90	0.19	0.53
	2015	334	7	0.71	0.28	0.68

[a] A permutation test of the difference in means was performed for each year.

The ratios of radiotagged Chinook salmon that passed each weir to the number of Chinook salmon that passed each weir are presented in Table 12. The ratios were similar for the Funny River and Killey River each year, except for 2015. In 2015, the ratio was higher for Killey River compared to the Funny River.

Table 12.–Ratio of radiotagged Chinook salmon that migrated past the Funny River and Killey River weirs to the number of Chinook salmon that passed the Funny River and Killey River weirs, 2012–2015.

	Funny River			Killey River		
Year	Radiotagged (*n*)	Weir passage (*N*)	Ratio of radiotagged (*n*): weir passage (*N*)	Radiotagged (*n*)	Weir passage (*N*)	Ratio of radiotagged (*n*): weir passage (*N*)
2012	5	879	0.006	12	1,602	0.007
2013	7	1,027	0.007	12	1,881	0.006
2014	19	1,308	0.015	24	1,713	0.014
2015[a]	7	1,727	0.004	18	2,653	0.007

[a] Number of radiotagged Chinook salmon was not weighted to account for different tag deployment rates during 2015.

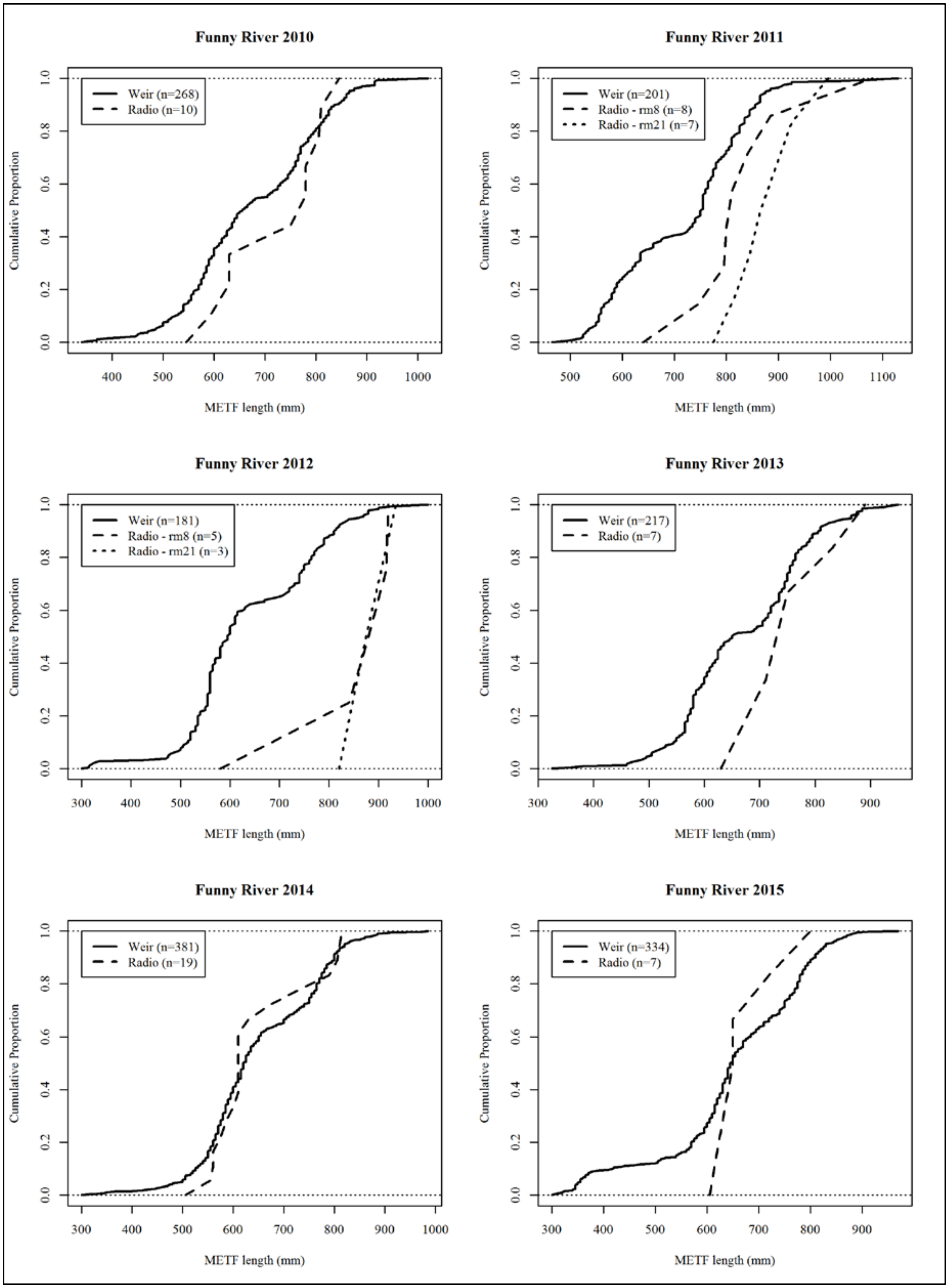

Figure 6.–Comparison of cumulative length distributions for radiotagged Chinook salmon that passed the Funny River weir and all Chinook salmon sampled at the Funny River weir, 2010–2015.

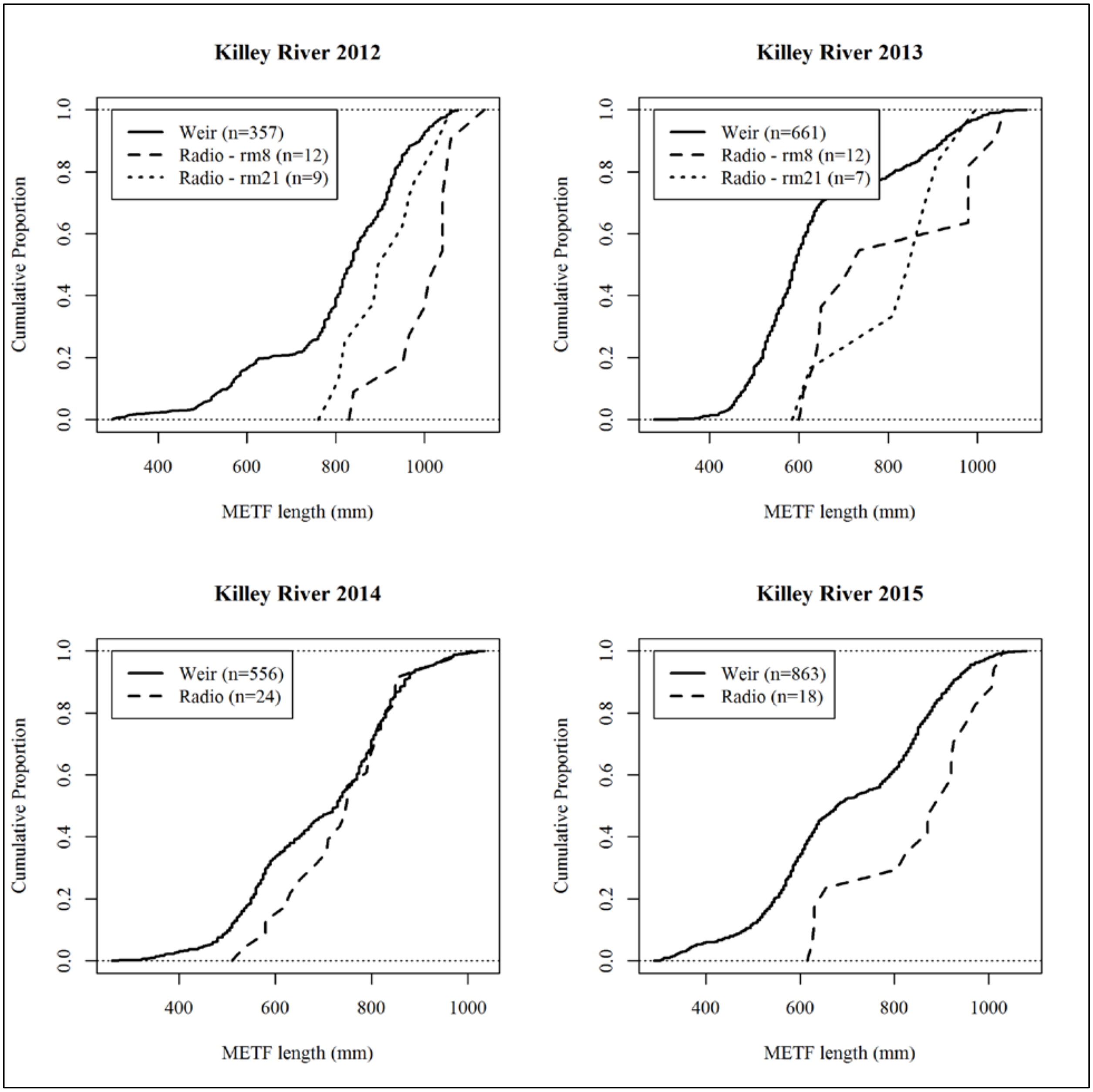

Figure 7.–Comparison of cumulative length distributions for radiotagged Killey River Chinook salmon that passed the Killey River weir and all Chinook salmon sampled at the Killey River weir, 2012–2015.

Mainstem Spawning Locations and Distribution

Spawning destinations for 2010–2013 were reanalyzed with more resolution and different criteria than in Reimer (2013) and thus supersede those reported in Reimer (2013). Spawning destinations reported herein are not intended to provide exact spawning destinations but provide the general vicinity where spawning probably occurred. Spawning activity could not be physically observed and the tracking locations obtained by boat were recorded as the place where the highest signal strength was received and not necessarily at the exact fish location. Mainstem spawning destinations are shown in Figure 8 for all years (2010–2014) late-run fish were not tagged in 2015. Higher resolution figures of mainstem spawning destinations are provided in Appendices A1–A7. Mainstem spawning destinations for radiotagged Chinook salmon were assigned throughout the Kenai River mainstem from the lower limit of tidal influence near RM 13 to RM 79. The area downstream of Soldotna Bridge had the highest percentage of mainstem spawners in every year (average 38%, range 35–40%), followed by the area from the Moose River confluence to Skilak Lake (average 28%, range 22–36%), the area between Soldotna Bridge and Moose River (average 21%, range 15–26%), and lastly the area from Skilak Lake to Kenai Lake, which had the smallest proportion of mainstem spawners during every year (average 12%, range 11–14%) (Table 13 and Figure 9). Spawning distribution proportions by geographic area reported for mainstem-spawning fish in past Kenai River Chinook salmon tagging studies during 1979, 1981, 1984, 1989 and 1990 are consistent with the spawning distribution proportions of mainstem-spawning fish tagged in 2012–2014 (Table 13) (Burger et al. 1983; Hammarstrom et al. 1985; Bendock and Alexandersdottir 1992). In past tagging studies, the upstream end of Naptowne Rapids (Bing's Landing) was the geographical boundary between the middle 2 areas whereas in the recent studies, the Moose River confluence is the geographical boundary between the middle 2 areas; this change was made in order to align with boundaries used in the Statewide Harvest Survey. The result of this change to geographic boundaries is small because very few fish spawn between the Moose River confluence and Bing's Landing compared to adjacent sections of the river (Figure 8).

Mainstem spawning destinations were also examined by river mile (Figure 10). Proportions of radiotagged mainstem spawning Chinook salmon by river mile were weighted by the number of spawning destinations assigned by year and the sampling rate, then pooled for 2010–2014. Radio tags deployed from RM 21.0 were not included in the analysis. Areas with high proportions of mainstem spawning Chinook salmon were RMs 13–20, 40, 44, and 46 (Figure 10). The river mile with the highest proportion of the assigned mainstem spawning destinations was RM 46, followed by RM 18 and 20. Mainstem spawning destinations were determined for radiotagged Chinook salmon within every river mile except for the slow deep water near lake outlets (RMs 49–50 and 65 near Skilak Lake and RMs 80–82 near Kenai lake), or large areas with rapids or large substrate in the upper Kenai River (RMs 67–68 in the Kenai Canyon, and RMs 76 and 77 above Schooners Bend).

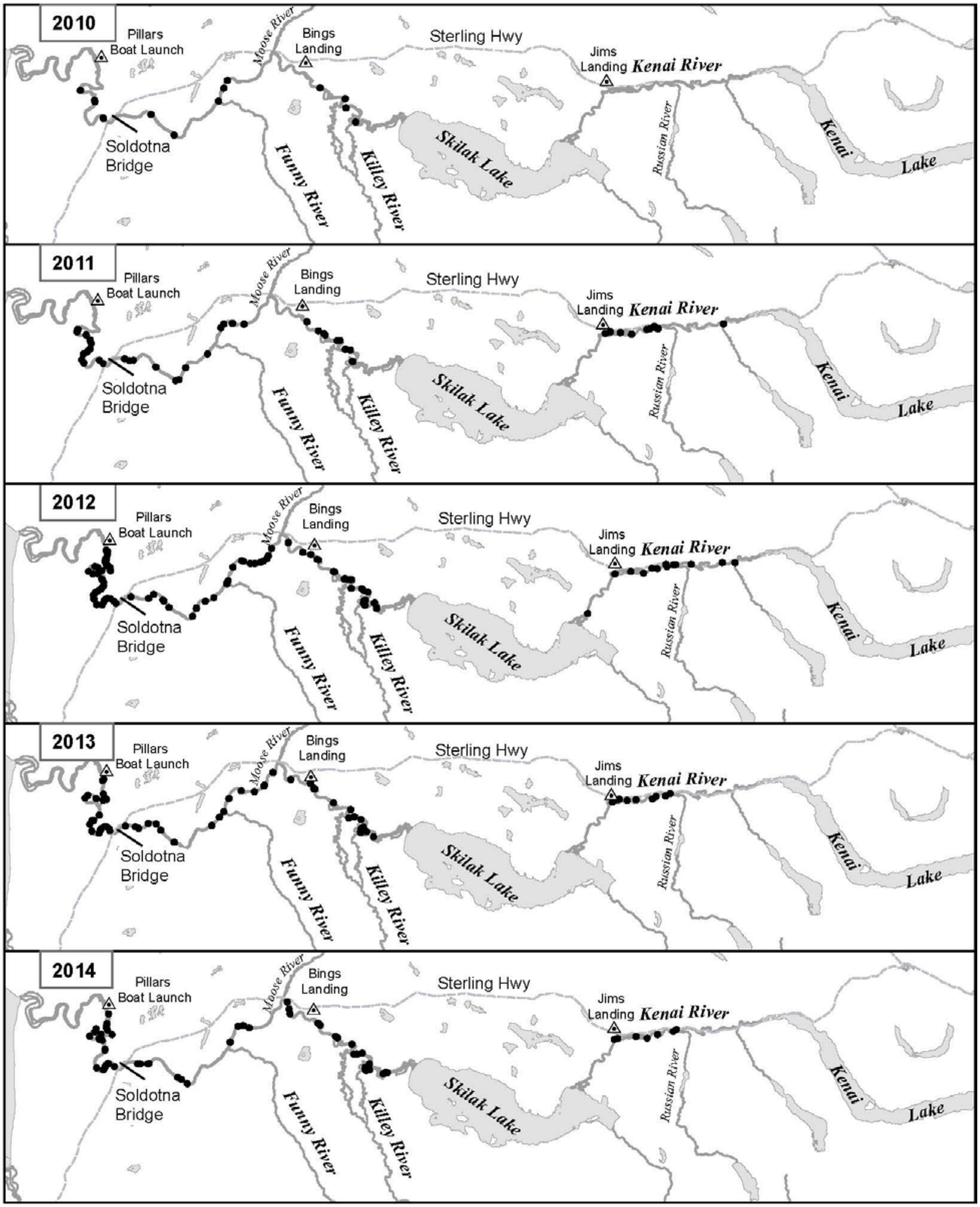

Figure 8.–Spawning destinations determined by year for radiotagged mainstem Kenai River spawning Chinook salmon captured at RM 8.6, 2012–2014.

Table 13.–Mainstem spawning distributions determined by geographic area Kenai River Chinook salmon radiotagged at RM 8.6 of the Kenai River, 2012–2014 with averages for radiotagging studies done in 1979, 1991, 1984, 1989, and 1990.

	Downstream of Soldotna Bridge		Soldotna Bridge to Moose River		Moose River to Skilak Lake		Skilak Lake to Kenai Lake	
Year	%	SE (%)	%	SE (%)	%	SE (%)	%	SE (%)
2012	40	5	26	5	22	5	12	3
2013	35	6	24	5	27	5	14	4
2014	39	6	15	4	36	6	11	4
Average								
2012–2014	38	3	21	3	28	3	12	2
1979,81,84,89,90	39	6	25	7	23	6	13	6

Source: (1979) Burger et al. 1983; (1984) Hammarstrom et al. 1985; (1990,1991) Bendock and Alexandersdottir 1990, 1991; (2010–2013) Reimer 2013.

Note: Geographic boundaries are slightly different for the 2012–2014 tagging studies compared to the older tagging studies. The older studies used Naptowne Rapids as the boundary between the middle 2 geographic boundaries whereas the Moose River is used during the recent studies to align with Statewide Harvest Survey estimates and recent management actions. Very little spawning occurs between the Moose River confluence and Naptowne Rapids.

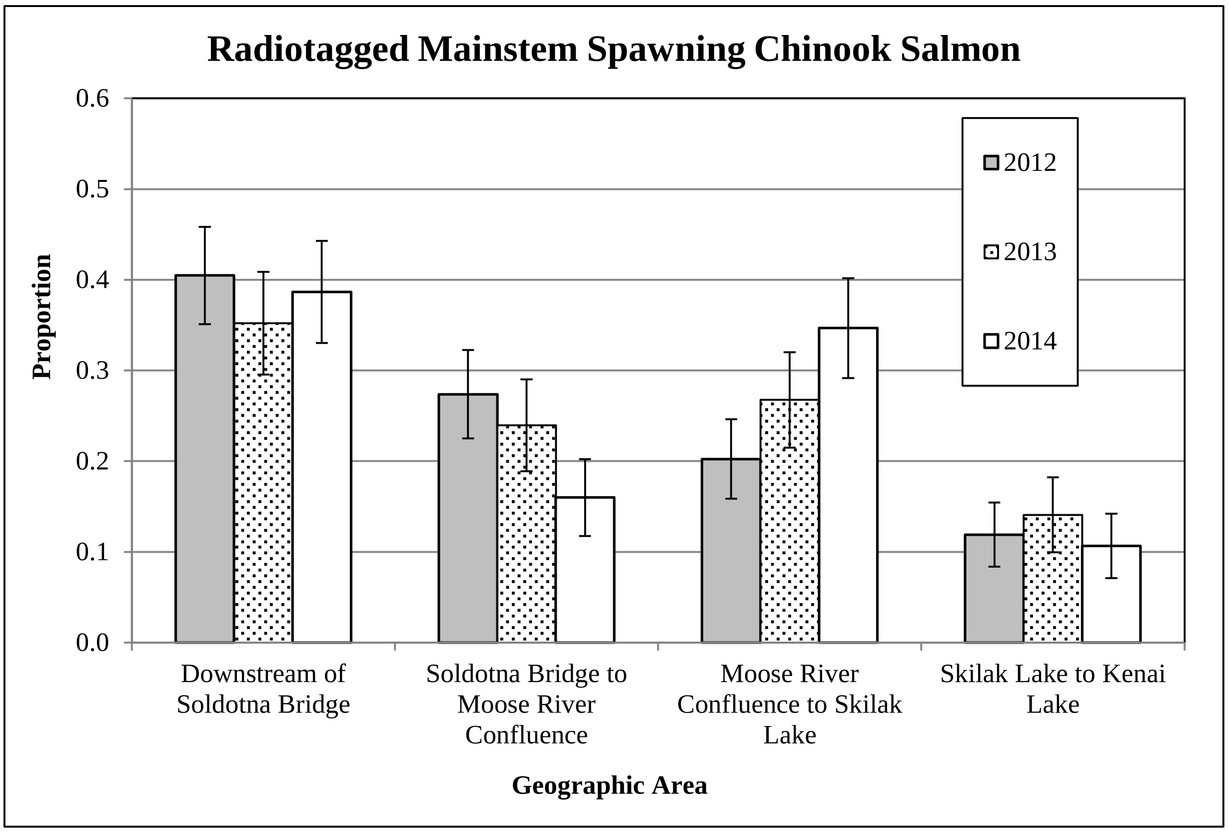

Figure 9.–Proportion by geographic area of Kenai River mainstem-spawning Chinook salmon radiotagged at RM 8.6, 2012–2014.

Note: Bars indicate standard errors of the mean. Downstream of Soldotna Bridge is RM 12.8–21; Soldotna Bridge to Moose River confluence is RM 21–36.3; Moose River confluence to Skilak Lake is RM 36.3–50; Skilak Lake to Kenai Lake is RM 65–82.

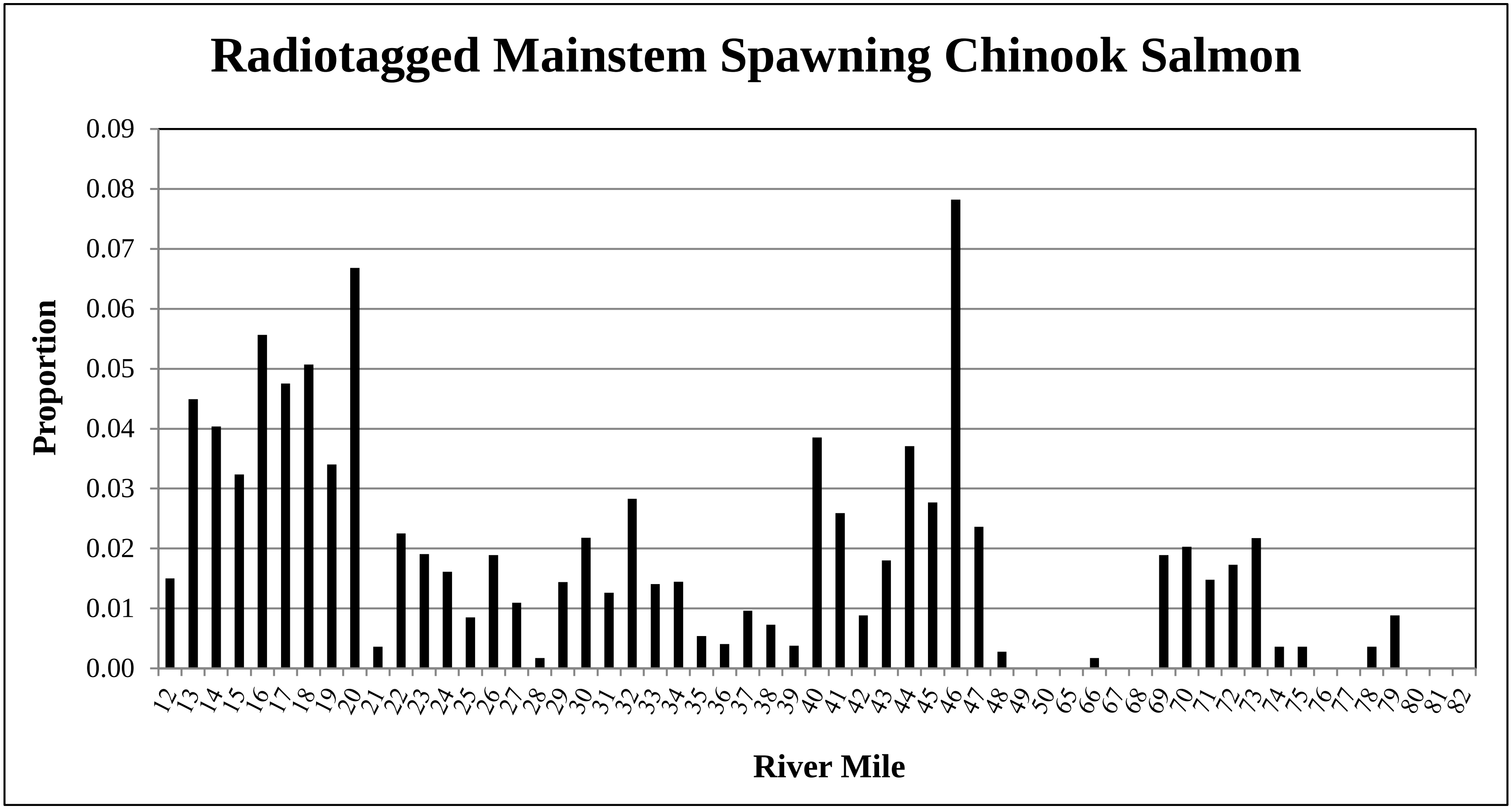

Figure 10.–Weighted proportion of radiotagged Kenai River mainstem spawning Chinook salmon by river mile, 2010–2014.

Mainstem Spawning Distribution Relative to RM 13.7 Chinook Salmon Sonar

Inseason management of Chinook salmon sonar transitioned from the RM 8.6 site used through 2014 to the RM 13.7 site in 2015. The new site at RM 13.7 is a short distance upstream of tidal influence and is located within suitable mainstem spawning habitat, and therefore some spawning does occur downstream of RM 13.7. For all radiotagged fish determined to be mainstem spawners, on average about 96% (SE 1.2%) spawned upstream of RM 13.7 during 2012–2014, ranging from 94.7% (SE 2.6%) in 2014 to 97.2% (SE 2.0%) in 2014 (Table 14). Mainstem spawning locations in relation to the RM 13.7 sonar was also determined by run (Table 14).

Spawning Destinations by Date of Capture

Mainstem spawning Chinook salmon that entered before July 1 (early run) appeared to spawn in the same areas as mainstem spawning Chinook salmon that entered after July 1 (late run) (Figure 11).

TRIBUTARY AND MAINSTEM SPAWNING COMPOSITION BY RUN

Proportions of fish radiotagged during the early run with spawning destinations in tributary and mainstem locations are summarized by year for 2010–2014 and compared to previous years (1980, 1981, 1990, and 1991) (Table 15). Tagging data from 2015 were not included because tags were not deployed during the entire early run. Tributary spawners composed the majority of fish tagged during the 2010–2014 early runs, ranging from 72% (SE 5%) in 2011 to 85% (SE 5%) in 2012. The 2010–2014 weighted[4] average was 79% (SE 3%) for tributary spawning fish during the early run and 21% (SE 3%) for mainstem spawning fish. In comparison to the averages for the 1990 and 1991 studies, the 2010–2014 weighted averages were nearly identical with similar ranges. The low mainstem proportions in 1980 and 1981 may not be comparable to other years due to low sample size.

MIGRATORY TIMING

Tributary spawners were analyzed by date of capture and mortality timing for 2014 and 2015 and tabulated with 2010–2013 results. Site fidelity dates were not determined for tributary spawners due to insufficient tracking resolution within tributaries. Streamlife of tributary spawners is also not reported herein because determinations could be biased by up to 14 days due to infrequent tracking flights. Mainstem spawners were analyzed by date of capture, spawning site fidelity timing, mortality timing, and streamlife for 2014 and tabulated with 2012 and 2013 results.

[4] Weighted by the number of tags deployed each year.

Table 14.–Number and proportion of mainstem spawning Kenai River Chinook salmon radiotagged near RM 8.6 that spawned upstream and downstream of RM 13.7 Chinook salmon sonar, 2012–2014.

	Early run				Late run				Both runs			
	Below RM 13.7		Above RM 13.7		Below RM 13.7		Above RM 13.7		Below RM 13.7		Above RM 13.7	
Year	N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)	N	% (SE%)
2012 [a]	1	16.7 (14.1)	6	85.7 (13.2)	4	3.4 (1.7)	112	96.6 (1.7)	5	4.1 (1.8)	118	95.9 (1.8)
2013	0	0.0 (0.0)	8	100.0 (0.0)	2	3.2 (2.2)	61	96.8 (2.2)	2	2.8 (2.0)	69	97.2 (2.0)
2014	0	0.0 (0.0)	18	100.0 (0.0)	4	6.9 (3.3)	54	93.1 (3.3)	4	5.3 (2.6)	72	94.7 (2.6)
Average	0.3	5.6 (4.7)	11	95.2 (4.4)	3	4.5 (1.4)	76	95.5 (1.4)	4	4.0 (1.2)	86	96.0 (1.2)

[a] Estimates for 2012 include Chinook salmon radiotagged in Cook Inlet.

Table 15.–Tributary and mainstem composition for Kenai River Chinook salmon tagged in the early run near RM 8.6.

	Tributary		Mainstem	
Year	N	% (SE)	N	% (SE)
1980	21	100 (0)	0	0 (0)
1981	18	95 (5)	1	5 (5)
1990	66	70 (5)	28	30 (6)
1991	70	91 (3)	7	9 (3)
2010	65	81 (9)	15	19 (5)
2011	56	72 (5)	22	28 (5)
2012	39	85 (5)	7	15 (5)
2013	29	78 (7)	8	22 (7)
2014	76	81 (4)	18	19 (4)
Average				
1980, 1981	20	98 (2)	1	3 (2)
1990, 1991	68	80 (3)	18	20 (3)
2010–2014	50	79 (3)	14	21 (3)
All years	49	81 (2)	12	19 (2)

Source: Burger et al. (1983) for 1980 and 1981; Bendock and Alexandersdottir (1990, 1991) for 1990 and 1991; and Reimer (2013) for 2010–2013.

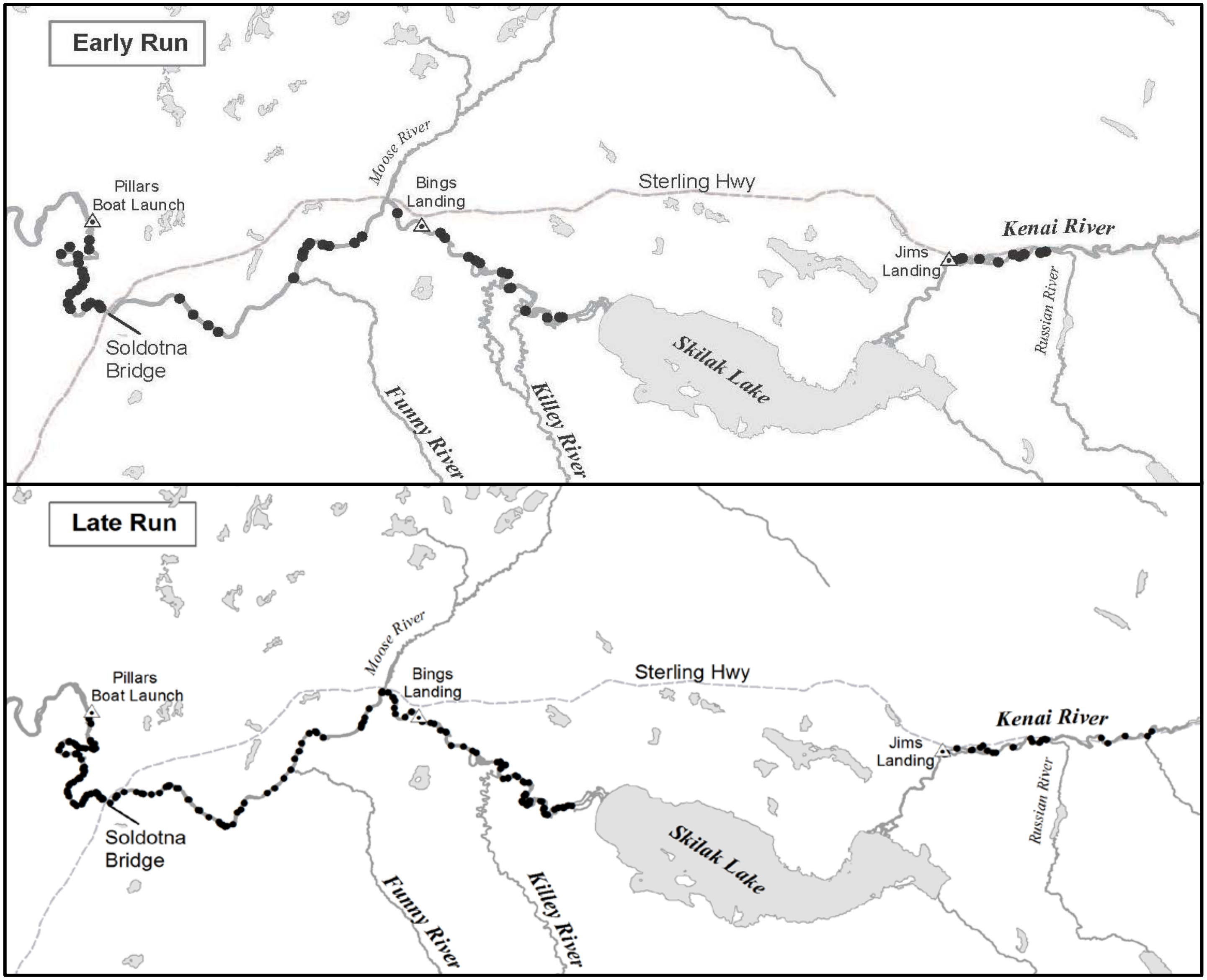

Figure 11.–Spawning destinations determined by run for radiotagged Kenai River mainstem spawning Chinook salmon captured at RM 8.6, 2012–2014.

Tributary Spawners

Date of Capture

Funny River, Killey River, and Benjamin Creek are classified as major tributary-spawning Chinook salmon streams in this report whereas Juneau Creek, Russian River, Quartz Creek, Grant Creek, Crescent Creek, Daves Creek, Trail River, and Slikok Creek are classified as minor tributary-spawning Chinook salmon streams (Tables 16 and 17). Skilak Lake is included as a minor Chinook salmon spawning destination in Table 17. Entry timing (capture date) for each tributary stock was similar among years. Radiotagged Chinook salmon bound for major spawning tributaries (Funny River, Killey River, and Benjamin Creek) were captured during the entire early run (dates prior to 1 July) with all years considered, but not during the entire early run in every year (Table 16). Among all years, Killey River and Benjamin Creek radiotagged fish were generally captured the earliest before Funny River fish (Table 16). Also, the overall median capture date was 8 June for Killey River fish, the while the overall median capture dates for Funny River and Benjamin Creek radiotagged fish were each 10 June (Table 16). No Funny River, Killey River, or Benjamin Creek radiotagged fish were captured in July during any year.

Most radiotagged Chinook salmon bound for minor spawning tributaries were not captured until mid-June (Table 17). Only 3 of the 28 radiotagged Chinook salmon that successfully migrated to minor tributaries (and Skilak Lake) were captured in May (20 May, Quartz Creek; 28 May, Skilak Lake; 31 May, Slikok Creek) (Table 17). Among the successful migrants to minor spawning tributaries, Juneau Creek had the most (n = 7) followed by Russian River (n = 5) of all minor tributaries (Table 17). Grant Creek and Quartz Creek each had 4 radiotagged fish. Skilak Lake had 3 radiotagged fish, Crescent Creek had 2 radiotagged fish and Daves Creek, Trail River, and Slikok Creek each had 1 radiotagged fish (Table 17).

Of the minor tributary-spawning Chinook salmon streams, Quartz Creek had the largest range of capture dates (20 May–4 July), whereas Grant Creek (including Trail River) and Russian River fish were only captured in late June (22–30 June) (Table 17). Radiotagged fish spawning in Skilak Lake were captured 28 May–14 June. Crescent Creek and Daves Creek radiotagged fish were captured 10–14 June. Juneau Creek radiotagged fish were generally captured in late June to early July except for 1 fish captured on 11 June. Lastly, a single Slikok Creek fish was captured on 31 May. Only 2 Chinook salmon bound for tributaries were captured in July (Juneau Creek, 9 July; Quartz Creek, 4 July) (Table 17). In general, radiotagged fish from the major Chinook salmon spawning tributaries were captured earlier than Chinook salmon bound for other areas.

Table 16.–Date of capture and mortality for radiotagged Chinook salmon found in major tributary-spawning Chinook salmon streams of the Kenai River (Funny River, Killey River, and Benjamin Creek), and for all tributary-spawning Chinook salmon streams of the Kenai River, 2010–2015.

Spawning destination	Year	N	Capture First	Capture Median	Capture Last	Mortality First	Mortality Median	Mortality Last
Funny River	2010	6	29 May	12 Jun	28 Jun	26 Jul	10 Aug	13 Aug
	2011	8	26 May	3 Jun	30 Jun	5 Jul	26 Jul	4 Aug
	2012	5	26 May	7 Jun	22 Jun	8 Jul	27 Jul	4 Aug
	2013	7	8 Jun	18 Jun	23 Jun	26 Jul	3 Aug	13 Aug
	2014	19	24 May	10 Jun	30 Jun	11 Jul	28 Jul	10 Aug
	2015	7	18 May	13 Jun	23 Jun	3 Jul	19 Jul	31 Jul
	All	52	18 May	10 Jun	30 Jun	5 Jul	3 Aug	13 Aug
Killey River	2010	21	19 May	9 Jun	19 Jun	2 Jul	29 Jul	17 Aug
	2011	23	17 May	8 Jun	28 Jun	5 Jul	30 Jul	12 Aug
	2012	21	19 May	3 Jun	27 Jun	5 Jul	25 Jul	16 Aug
	2013	6	7 Jun	8 Jun	14 Jun	15 Jul	22 Jul	3 Aug
	2014	30	18 May	9 Jun	15 Jun	10 Jul	4 Aug	14 Aug
	2015	13	22 May	3 Jun	9 Jun	3 Jul	26 Jul	31 Jul
	All	114	17 May	8 Jun	28 Jun	2 Jul	28 Jul	17 Aug
Benjamin Creek	2010	15	20 May	11 Jun	27 Jun	26 Jul	13 Aug	13 Aug
	2011	22	3 Jun	9 Jun	21 Jun	16 Jul	4 Aug	12 Aug
	2012	10	16 May	2 Jun	20 Jun	16 Jul	27 Jul	4 Aug
	2013	9	22 May	8 Jun	26 Jun	22 Jul	26 Jul	3 Aug
	2014	20	1 Jun	12 Jun	22 Jun	23 Jul	7 Aug	8 Aug
	2015	15	2 Jun	4 Jun	25 Jun	19 Jul	26 Jul	31 Jul
	All	91	16 May	10 Jun	27 Jun	16 Jul	4 Aug	13 Aug
All tributaries [a]	2010	47	19 May	11 Jun	28 Jun	2 Jul	10 Aug	17 Aug
	2011	56	17 May	8 Jun	30 Jun	5 Jul	4 Aug	17 Aug
	2012	39	16 May	4 Jun	27 Jun	5 Jul	26 Jul	16 Aug
	2013	25	20 May	11 Jun	9 Jul	15 Jul	27 Jul	13 Aug
	2014	76	18 May	10 Jun	4 Jul	10 Jul	7 Aug	14 Aug
	2015	37	18 Jun	7 Jun	25 Jun	3 Jul	19 Jul	31 Jul
	All	280	16 May	8 Jun	9 Jul	2 Jul	31 Jul	17 Aug

[a] Data include major and minor Kenai River Chinook salmon producing tributaries (see Table 17 for details on minor tributaries).

Table 17.–Number captured, date of capture, and date of mortality for radiotagged Chinook salmon found in minor Kenai River Chinook salmon–producing tributaries and locations, 2010–2015.

Spawning destination	Year	Capture date	Mortality date
Juneau Creek (*n* = 7)	2010	26 Jun	na
	2011	29 Jun	17 Aug
	2012	11 Jun	1 Aug
	2012 [a]	20 Jun	na
	2013	9 Jul	na
	2014	19 Jun	na
	2015	26 Jun	na
Russian River (*n* = 5)	2010	22 Jun	13 Aug
	2014	25 Jun	na
	2014	30 Jun	na
	2014	30 Jun	na
	2015	23 Jun	na
Quartz Creek (*n* = 4)	2011 [a]	15 Jun	4 Aug
	2012 [a]	13 Jun	5 Aug
	2013	20 May	15 Jul
	2014	4 Jul	8 Aug
Grant Creek (*n* = 4)	2010	27 Jun	na
	2011	30 Jun	na
	2012	22 Jun	na
	2012	24 Jun	na
Skilak Lake (*n* = 3) [b]	2010	28 May	na
	2010	14 Jun	22 Jul
	2014	4 Jun	27 Jul
Crescent Creek (*n* = 2)	2010	14 Jun	9 Aug
	2013	11 Jun	3 Aug
Daves Creek (*n* = 1)	2010	10 Jun	11 Aug
Trail River (*n* = 1)	2014	28 Jun	na
Slikok Creek (*n* = 1)	2011	31 May	11 Aug

Note: The term "na" means data not available.

[a] Chinook salmon radiotagged at RM 21.0; all others radiotagged at RM 8.6.

[b] Skilak Lake is not a Kenai River tributary; however, it is listed in this table.

Mortality

Mortalities were detected for radiotagged Chinook salmon with tributary spawning destinations beginning in early July and continuing through mid-August (Tables 16 and 17). However, mortality dates for some tributary-spawning Chinook salmon were not determined because fish were still alive after the last aerial survey of the year was conducted. That was particularly the case for tributaries with later return timing such as Russian River and Grant Creek. The median mortality date for tributary spawners was 31 July for all years; however, this date has an early bias to a small degree because the date of mortality was not determined for a few of the latest-surviving radiotagged tributary spawners.

Use of the Funny River and Killey River Closed Areas

The number of radiotagged Chinook salmon present in the Funny and Killey rivers closed areas by date was determined for 2014 but not for 2015 due to limited boat tracking and insufficient resolution from fixed stations. For Funny River–bound radiotagged fish, the first fish arrived in the closed area on 2 June in 2014, and the last fish departed and entered the Funny River on 25 July (Figure 12). In 2014, Funny River fish were present in the closed area earlier than in 2010–2013 but migrated into Funny River over a similar range of dates. The largest numbers of Funny River bound radiotagged Chinook salmon were present in the closed area from late June to almost mid-July (Figure 12). All radiotagged Chinook salmon bound for the Funny River were in the closed area as early as 7 July in 2014 but as late as 19 July in 2011 and 2013 (Table 18).

Killey River bound radiotagged fish have been present in the Killey River closed area as early as the end of May (Reimer 2013), but did not enter the closed area until 20 June in 2014 (Figure 13). The date when all Killey River bound radiotagged Chinook salmon had entered the Killey River closed area was 13 July in 2014 and 1 July in 2015 (Table 18). Killey River fish generally staged within the Killey River closed area for less time than Funny River fish staged in the Funny River closed area. The largest numbers of Killey River bound radiotagged Chinook salmon were located in the Killey River closed area in late June to mid-July in 2014 which is similar to other years (Figure 13). In general, the largest numbers of radiotagged Chinook salmon bound for spawning in the Killey River aggregated in the Killey River closed area during the same time period as when the largest number of Funny River bound radiotagged fish were in the Funny River closed area (Table 18, Figures 12 and 13).

Table 18.–Date of last Funny River and Killey River bound radiotagged Chinook salmon to enter the Funny and Killey River closed areas and each tributary by year, 2010–2015.

	Funny River		Killey River	
Year	Date all entered closed area	Date all entered Funny River	Date all entered closed area	Date all entered Killey River
2010	16 Jul	1 Aug	14 Jul	1 Aug
2011	19 Jul	21 Jul	10 Jul	26 Jul
2012	8 Jul	8 Jul	20 Jul	26 Jul
2013	19 Jul	22 Jul	7 Jul	12 Jul
2014	7 Jul	24 Jul	13 Jul	20 Jul
2015	18 Jul	20 Jul	1 Jul	17 Jul
Latest date (2010–2015)	19 Jul	1 Aug	20 Jul	1 Aug

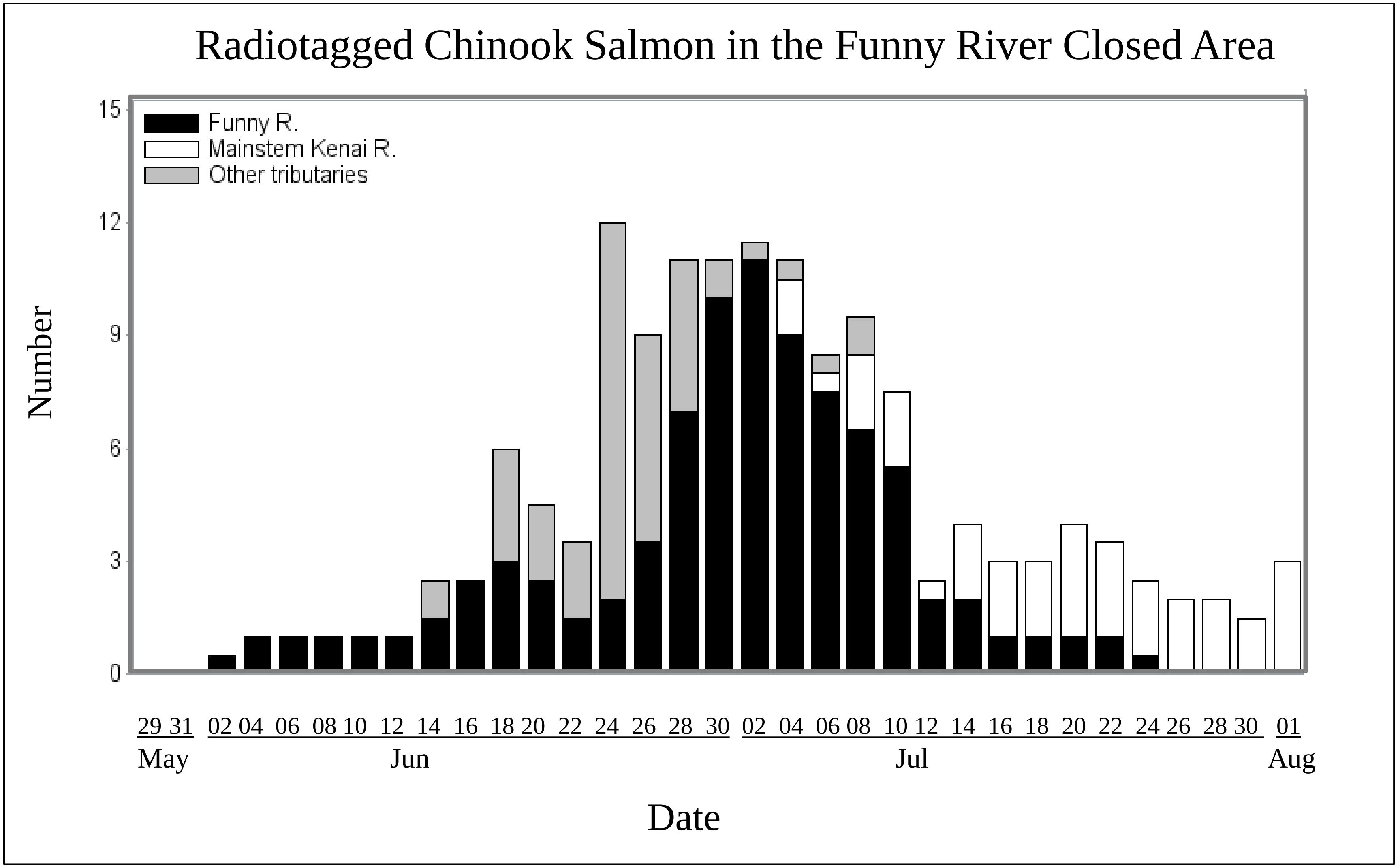

Figure 12.–Number of radiotagged Kenai River Chinook salmon in the Funny River closed area by spawning destination and date, 2014.

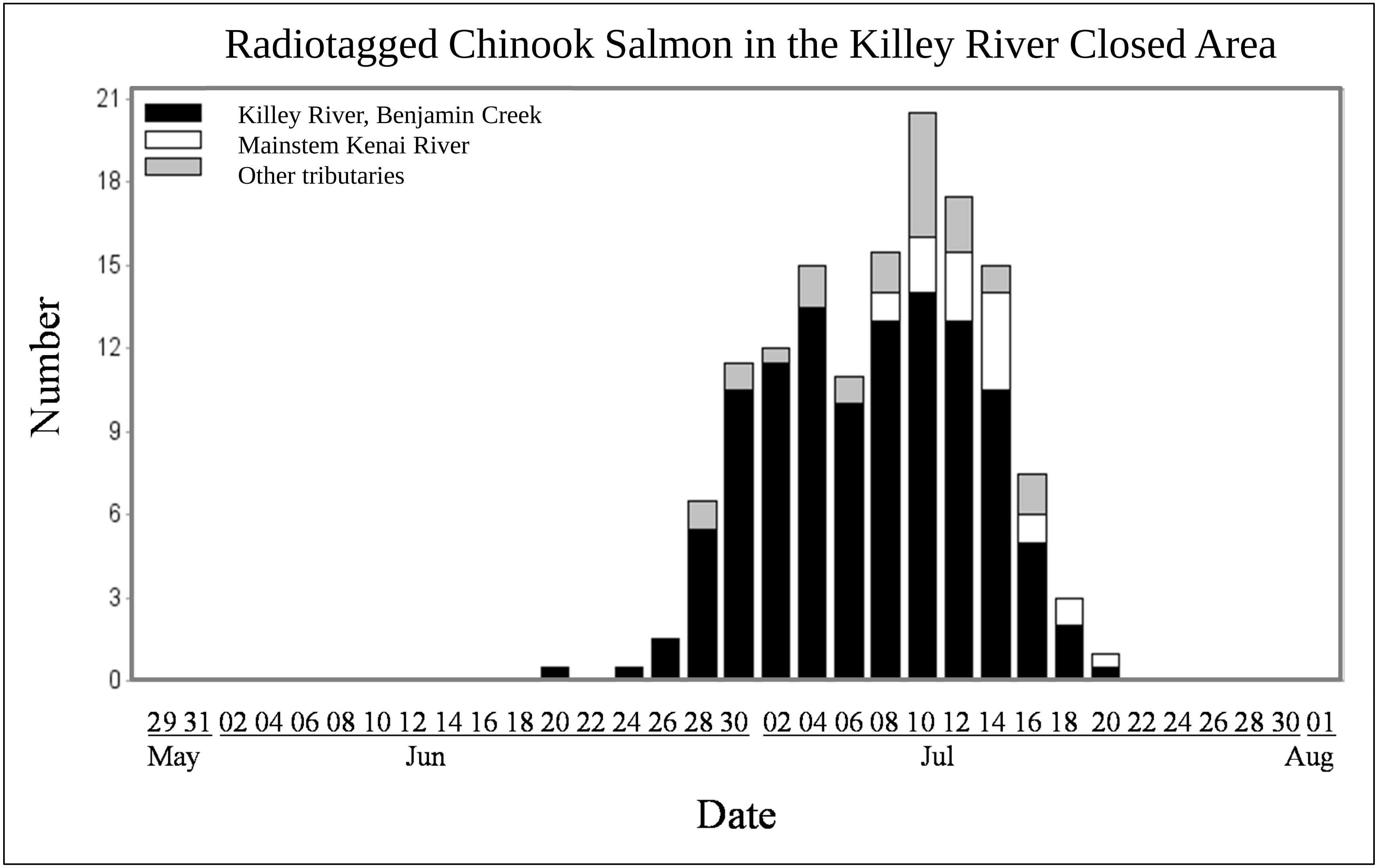

Figure 13.–Number of radiotagged Kenai River Chinook salmon in the Killey River closed area by spawning destination and date, 2014.

Mainstem Spawners

Date of Capture

Mainstem-spawning fish were first captured at RM 8.6 beginning in the first or second week in June. The earliest radiotagged Chinook salmon assigned a mainstem spawning destination in 2014 was captured on 2 June (Table 19). In previous years, the earliest Chinook salmon assigned a mainstem spawning destination were captured on 9 June and 13 June. This finding supports genetic-based results that indicate mainstem-spawning fish begin instream migration during early to mid-June (McKinley et al. 2013).

The overall 2010–2014 median date of capture for mainstem spawning fish was 21 July (Table 19). The median capture dates for fish assigned spawning destinations were earliest for the area between Skilak Lake and Kenai Lake and latest for the area between Soldotna Bridge and Moose River. Overall, the other 2 areas (Downstream of Soldotna Bridge and Moose River to Skilak Lake) had similar median dates of capture each year.

Site Fidelity

Mainstem spawners began displaying site fidelity to their eventual spawning area as early as mid to late June although in most cases site fidelity was first displayed in mid-July. The median date for the beginning of site fidelity was 18 August for all years (2012–2014) and river sections (Table 19). All radiotagged Chinook salmon with a mainstem spawning destination displayed site fidelity to their eventual spawning area by early September. Site fidelity ranged from 6 days (the established minimum criteria) to 72 days; the median duration of site fidelity for all mainstem spawning fish was 12 days. Spawning is assumed to have occurred toward the end of each fish’s site fidelity period, followed by mortality.

Mortality

Mainstem-spawning fish radiotagged in July and August had a narrow window when most mortalities occurred, whereas fish radiotagged in June had a broader range of dates when most mortalities occurred. Mortalities were earliest for fish tagged in June and latest for fish tagged in August. For mainstem-spawning fish radiotagged in June, 75% of mortalities occurred during 26 days from 3–28 August (Figure 14). For mainstem spawning fish radiotagged in July, 75% of fish were classified as mortalities during an 8 day window during 26 Aug–3 Sept. For mainstem spawning fish radiotagged in August, 50% of fish (interquartile range) were classified as mortalities during an 8 day window between 3–11 Sept. Mortalities for radiotagged mainstem spawning Chinook salmon were recorded as early as 13 July and as late as 23 September (Table 19); however the median date of mortality only ranged from 29–31 August during 2012–2014.

Streamlife

Streamlife averaged 33 days for all radiotagged mainstem-spawning fish during 2010–2014. Streamlife was longest (median 57.5 days) for mainstem-spawning fish radiotagged in June and shortest (median 30 days) for fish radiotagged in August (Figure 15). Mainstem spawners radiotagged in June had the largest interquartile range of streamlife days (42–63 days) compared to fish tagged in July (38–51 days) or August (24–34 days). Although streamlife was longest for fish radiotagged in June, mortality dates were still earlier on average than fish radiotagged in July and August (Figure 14).

Table 19.–Date of capture, beginning of spawning site fidelity, and date of mortality by geographic area for radiotagged mainstem-spawning Kenai River Chinook salmon, 2012–2014.

			Capture			Site fidelity			Mortality		
Geographic area	Year	N	First	Median	Last	First	Median	Last	First	Median	Last
Downstream of Soldotna Bridge											
	2012	34	27 Jun	30 Jul	14 Aug	20 Jul	19 Aug	1 Sep	1 Aug	30 Aug	13 Sep
	2013	25	9 Jun	17 Jul	15 Aug	26 Jul	16 Aug	9 Sep	13 Aug	29 Aug	17 Sep
	2014	29	2 Jun	21 Jul	9 Aug	13 Jun	17 Aug	27 Aug	13 Jul	31 Aug	10 Sep
	2012–2014	88	2 Jun	24 Jul	15 Aug	13 Jun	17 Aug	9 Sep	13 Jul	30 Aug	17 Sep
Soldotna Bridge to Moose River											
	2012	21	13 Jun	1 Aug	10 Aug	31 Jul	20 Aug	7 Sep	15 Aug	31 Aug	18 Sep
	2013	16	11 Jun	10 Jul	14 Aug	28 Jun	16 Aug	1 Sep	17 Jul	28 Aug	16 Sep
	2014	11	19 Jun	22 Jul	15 Aug	26 Jun	19 Aug	31 Aug	20 Aug	31 Aug	10 Sep
	2012–2014	48	11 Jun	29 Jul	14 Aug	27 Jul	19 Aug	7 Sep	17 Jul	31 Aug	18 Sep
Moose River to Skilak Lake											
	2012	19	14 Jun	25 Jul	7 Aug	7 Jul	21 Aug	30 Aug	17 Jul	1 Sep	15 Sep
	2013	14	17 Jun	12 Jul	16 Aug	9 Jul	16 Aug	6 Sep	28 Jul	29 Aug	17 Sep
	2014	26	17 Jun	18 Jul	9 Aug	11 Jul	17 Aug	7 Sep	20 Jul	4 Sep	23 Sep
	2012–2014	46	14 Jun	18 Jul	16 Aug	7 Jul	18 Aug	7 Sep	17 Jul	2 Sep	23 Sep
Skilak Lake to Kenai Lake											
	2012	10	27 Jun	17 Jul	3 Aug	1 Aug	12 Aug	2 Sep	19 Aug	26 Aug	10 Sep
	2013	9	21 Jun	18 Jul	14 Aug	24 Jul	18 Aug	4 Sep	25 Aug	2 Sep	10 Sep
	2014	8	20 Jun	18 Jul	2 Aug	26 Jul	16 Aug	19 Aug	3 Aug	27 Aug	1 Sep
	2012–2014	27	20 Jun	18 Jul	14 Aug	24 Jul	16 Aug	4 Sep	3 Aug	31 Aug	10 Sep
Entire Kenai River											
	2012	84	13 Jun	27 Jul	14 Aug	7 Jul	20 Aug	7 Sep	17 Jul	31 Aug	18 Sep
	2013	51	9 Jun	14 Jul	16 Aug	28 Jun	16 Aug	9 Sep	17 Jul	29 Aug	17 Sep
	2014	74	2 Jun	19 Jul	15 Aug	13 Jun	19 Aug	7 Sep	13 Jul	31 Aug	23 Sep
	2012–2014	209	2 Jun	21 Jul	16 Aug	13 Jun	18 Aug	9 Sep	13 Jul	31 Aug	23 Sep

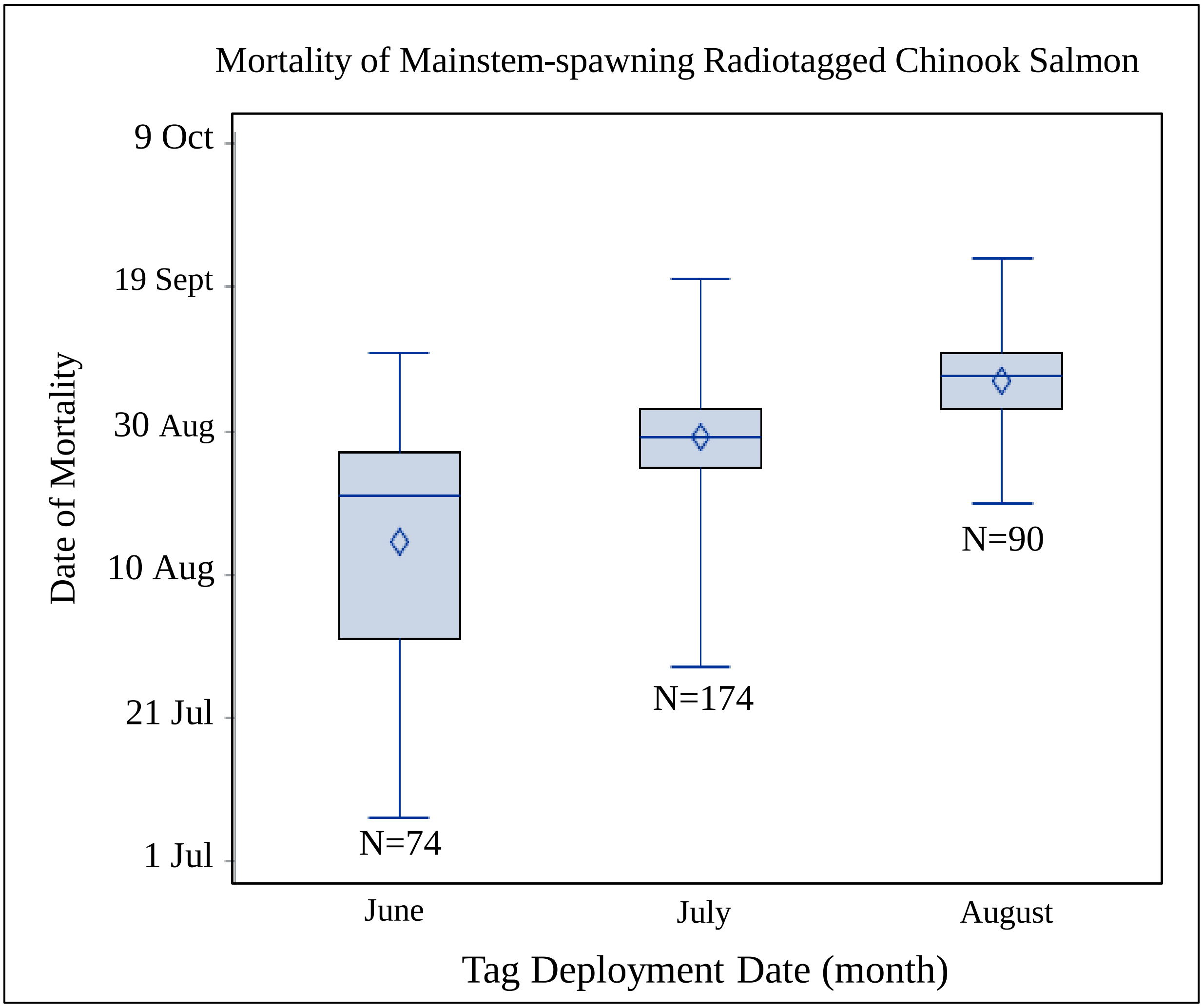

Figure 14.–Boxplot of mortality dates of radiotagged mainstem-spawning Chinook salmon by tag deployment date (month), Kenai River, 2010–2014.

Note: Whiskers indicate the minimum and maximum, boxes indicate 25th and 75th percentiles, diamonds indicate the average, and the horizontal lines inside the boxes indicate the median.

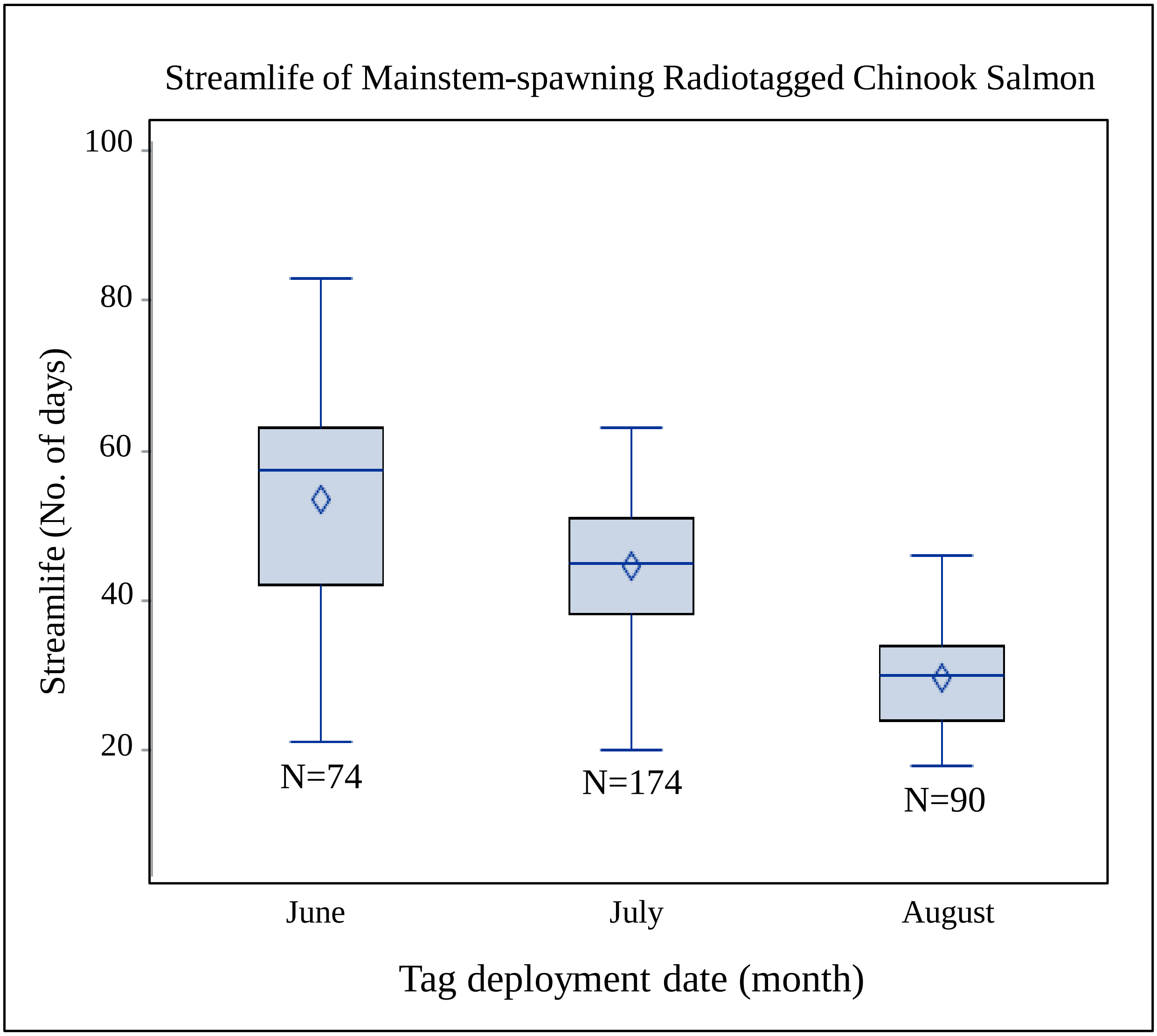

Figure 15.–Boxplot of streamlife (number of days) of radiotagged mainstem-spawning Chinook salmon by tag deployment date (month), Kenai River, 2010–2014.

Note: Whiskers indicate the minimum and maximum, boxes indicate 25th and 75th percentiles, diamonds indicate the average, and the horizontal line inside the boxes indicate the median.

Composition in Open Waters Downstream of Slikok Creek Sanctuary

The majority of radiotagged Chinook salmon detected within waters open to sport fishing downstream of Slikok Creek during May and most of June were assigned tributary spawning destinations (Figure 16; Appendix B1). Tributary spawning Chinook salmon were present downstream of Slikok Creek (RM 18.5) until 6 July in 2014 (Appendix B1). On 1 July in 2014, 36% (SE 15%) of radiotagged fish were tributary spawners compared to 40% (SE 22%) in 2012 and 0% (SE 0%) in 2013. Almost all of the Chinook salmon present downstream of Slikok Creek were mainstem spawners in July during all years (Appendix B1).

Composition in Open Waters Upstream of Slikok Creek Sanctuary

In waters open to sport fishing upstream of Slikok Creek, both mainstem and tributary spawners were present at different points in the run. On 1 July, most of the radiotagged fish upstream of Slikok Creek were tributary spawners (Figure 16). Tributary spawners were in waters open to sport fishing upstream of Slikok Creek through July in 2014, but not located in that area after 20 July in 2012 or after 22 July in 2013 (Appendix B1). Mainstem spawners were first located on 23 June in 2014 and remained present through July. By 15 July and through the end of July 2012–2014, mainstem spawners composed the majority of fish in waters open to sport fishing upstream of Slikok Creek (Figure 16).

DISTRIBUTION WITHIN MANAGEMENT AREAS

Kenai River Chinook salmon fishery management differs by year, time of year, and river section. Herein we use RM 18.5 (Slikok Creek) to separate the Kenai River sport fishery into 3 areas: RM 0–18.5, unrestricted waters upstream of RM 18.5, and closed or restricted waters upstream of RM 18.5. Closed or restricted waters include sanctuary areas around the confluences of Slikok Creek, Funny River, and Killey River and the boat-restricted fishing areas near Centennial Park and upstream of Funny River (Morgan’s Landing). The proportional distribution of Chinook salmon relative to these 3 areas is presented relative to date of capture (early run or late run) and assigned spawning destination (mainstem or tributary). Data for 2014 are presented in Appendices C1–C4 to complement those already published in Reimer (2013). Herein we use a generalized additive model to combine information from for 2010–2014 (Figures 17–20 and Appendices D1–D4).

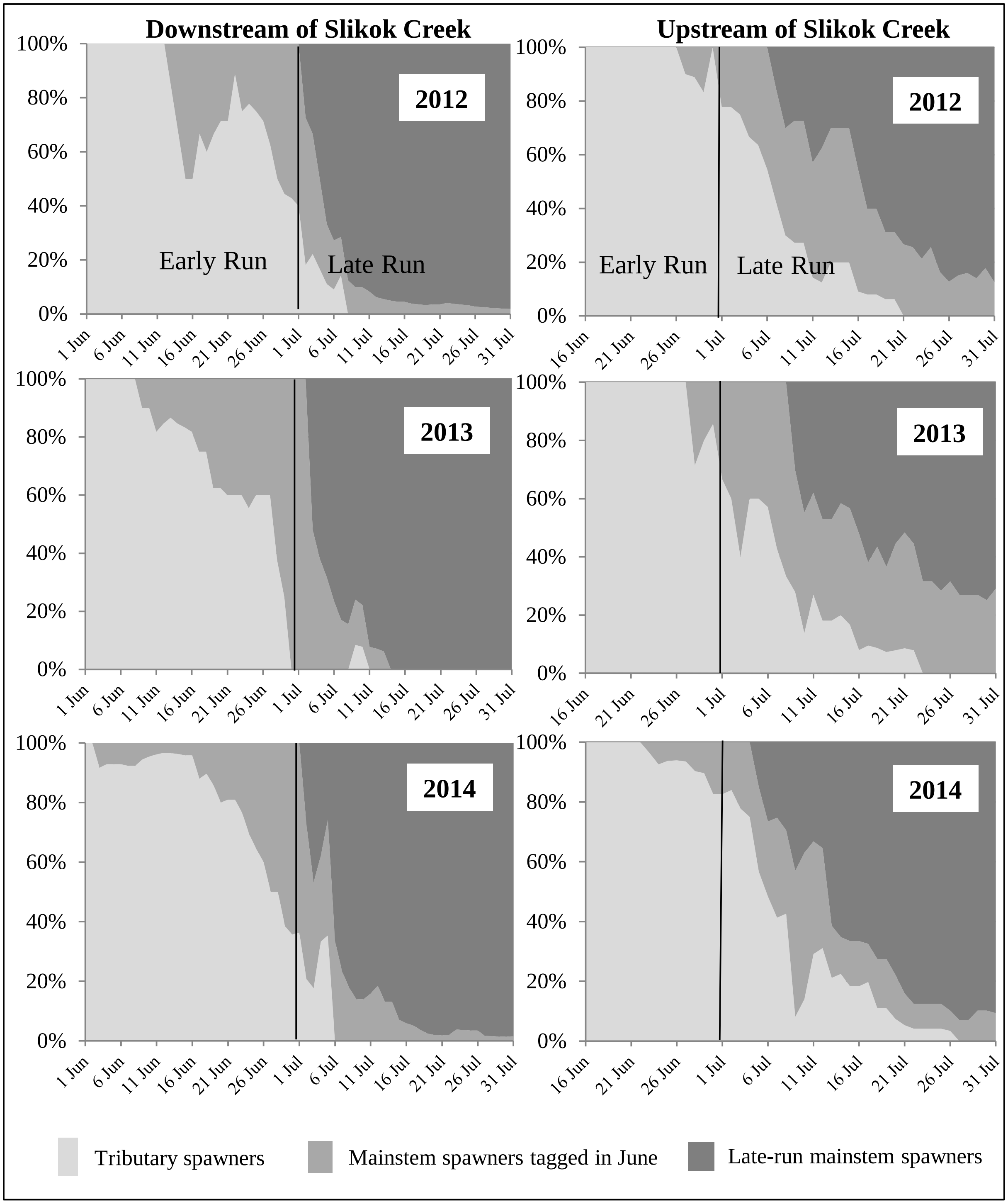

Figure 16.–Proportion of radiotagged Kenai River Chinook salmon upstream and downstream of Slikok Creek by date as assigned by spawning destination and tagging date, 2012–2014.

Note: The division is shown between dates for "early" and "late" runs as designated by management.

Note: "Upstream of Slikok Creek" excludes the closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River plus the Kenai River upstream of and including Skilak Lake.

Distribution by Date of Capture

Early Run

Chinook salmon that were radiotagged in the early run began migrating upstream of Slikok Creek in the second half of May and progressively entered closed or restricted fishing areas shortly thereafter (Figure 17). Early-run radiotagged fish upstream of Slikok Creek (RM 18.5) were generally evenly distributed among unrestricted and closed or restricted waters by mid-June, after which time the majority moved into closed or restricted waters. The highest proportion of early-run tagged fish upstream of Slikok Creek in unrestricted waters was in mid to late June. In July, early-run radiotagged fish continued to migrate into closed or restricted waters while exiting both sections of the fishery (upstream and downstream of Slikok Creek). Less than 20% of early-run Chinook salmon remained in waters open to sport fishing through July (Figure 17).

On 1 July, the smoothed proportional distribution of early run Chinook salmon was 18% (95% CI 16–19%) downstream of Slikok Creek, 23% (95% CI 21–25%) in unrestricted waters upstream of Slikok Creek, and 59% (95% CI 57–61%) in closed or restricted waters upstream of Slikok Creek (Appendix D1). On 15 July the smoothed proportional distribution of early run Chinook salmon was 6% (95% CI 5–7%) downstream of Slikok Creek, 11% (95% CI 10–13%) in unrestricted waters upstream of Slikok Creek, and 83% (95% CI 81–84%) in closed or restricted waters upstream of Slikok Creek (Appendix D1).

Late Run

Chinook salmon that were radiotagged on or after 1 July (late run) began migrating upstream of Slikok Creek early in July while small numbers entered closed or restricted fishing areas shortly thereafter (Figure 18). After the second week in July, the percentages of radiotagged late-run fish in each management area varied only slightly (Figure 18). On 15 July the smoothed proportional distribution of late-run Chinook salmon was 68% (95% CI 62–73%) downstream of Slikok Creek, 25% (95% CI 21–29%) in unrestricted waters upstream of Slikok Creek, and 10% (95% CI 8–14%) in closed or restricted waters upstream of Slikok Creek (Appendix D2).

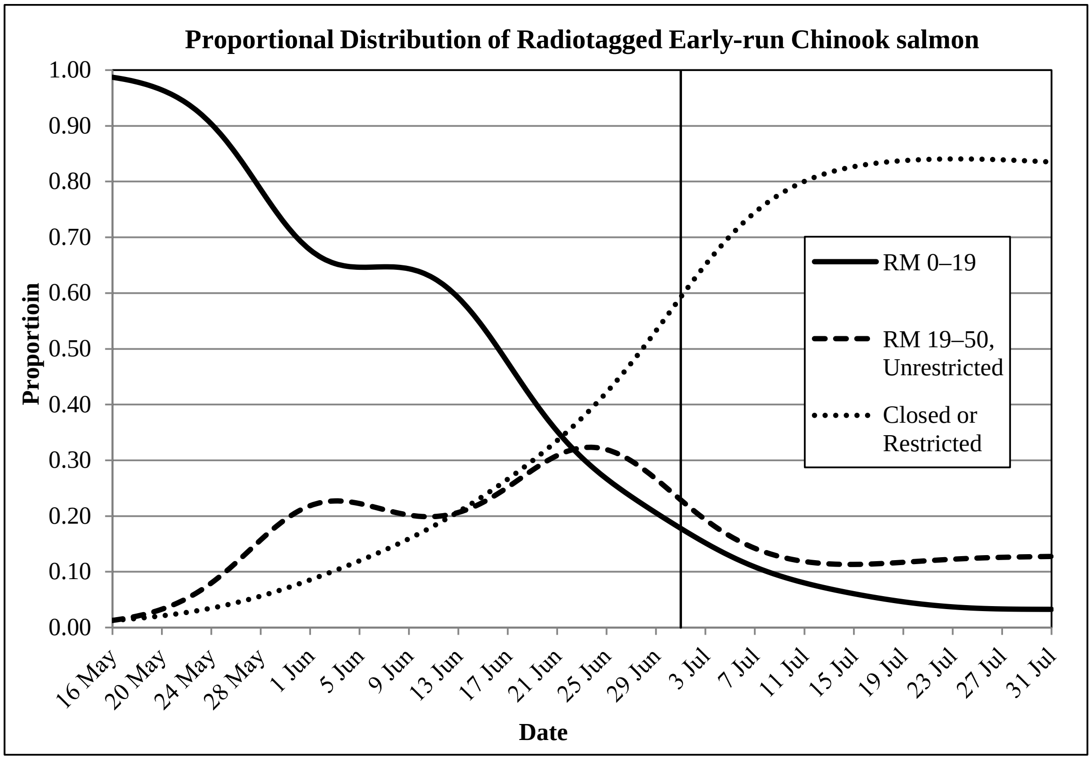

Figure 17.–Proportional distribution by date and area of Kenai River Chinook salmon radiotagged during the early run using a generalized additive model for 2010–2014.

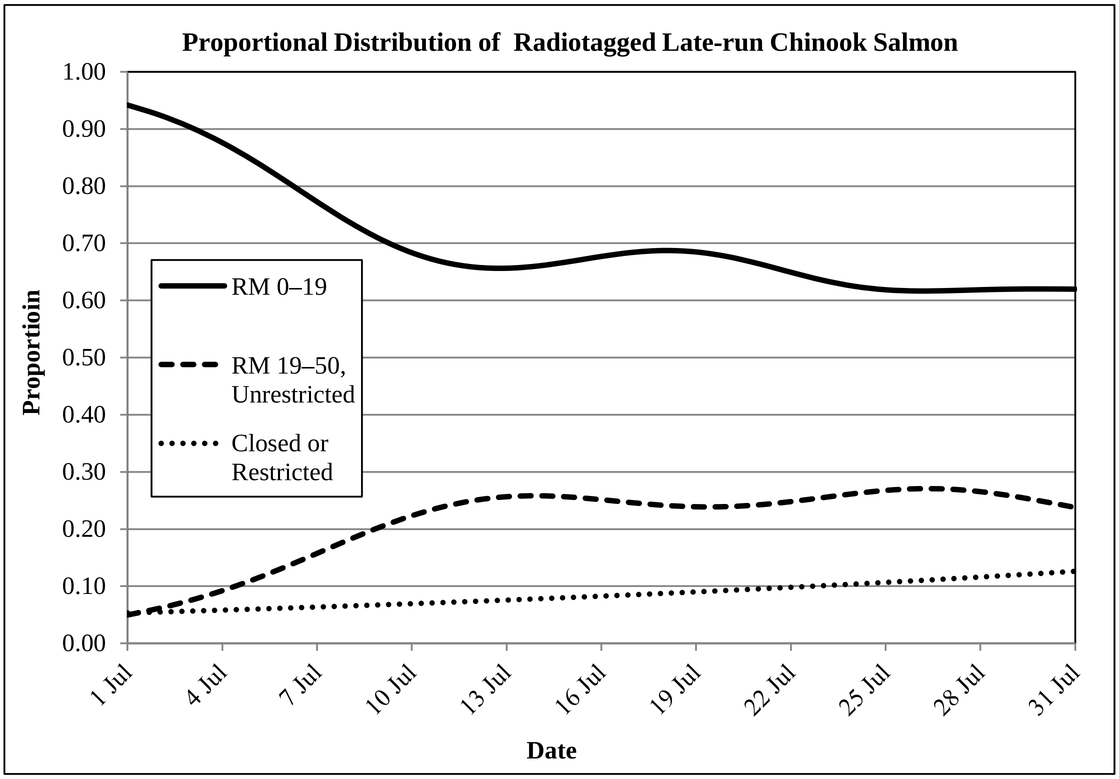

Figure 18.–Proportional distribution by date and area of Kenai River Chinook salmon radiotagged during the late run using a generalized additive model for 2012–2014.

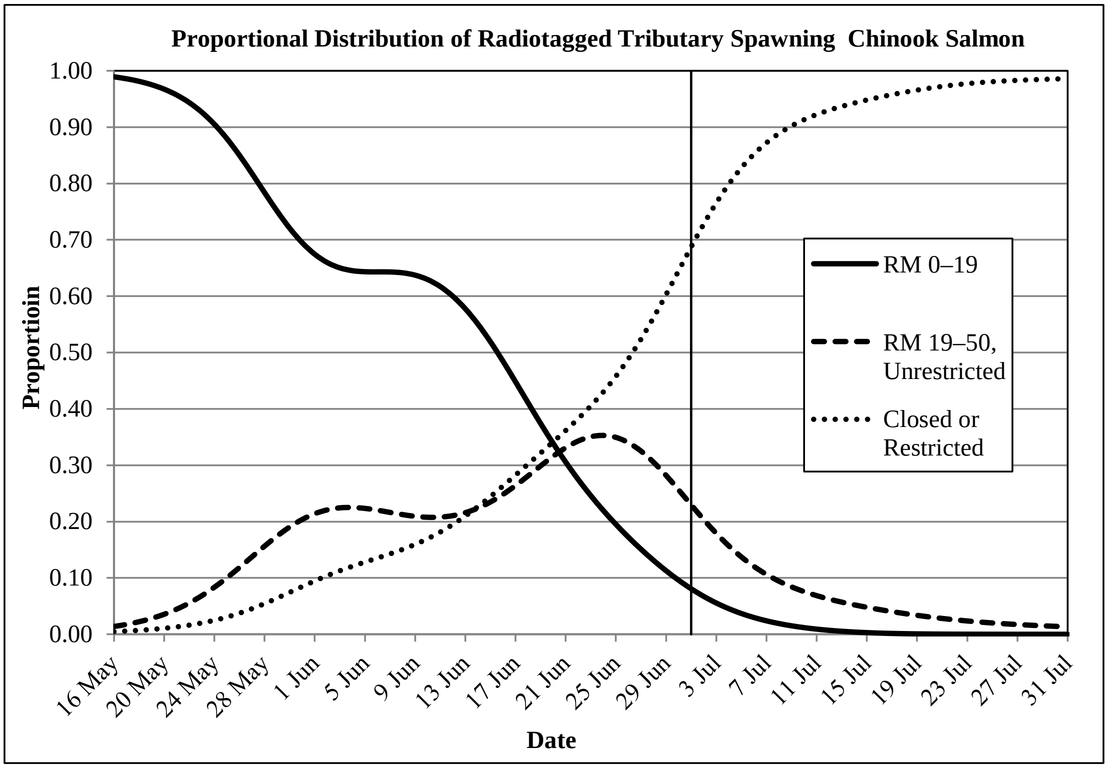

Figure 19.–Proportional distribution by date and area of radiotagged tributary spawning Kenai River Chinook salmon using a generalized additive model for 2010–2014.

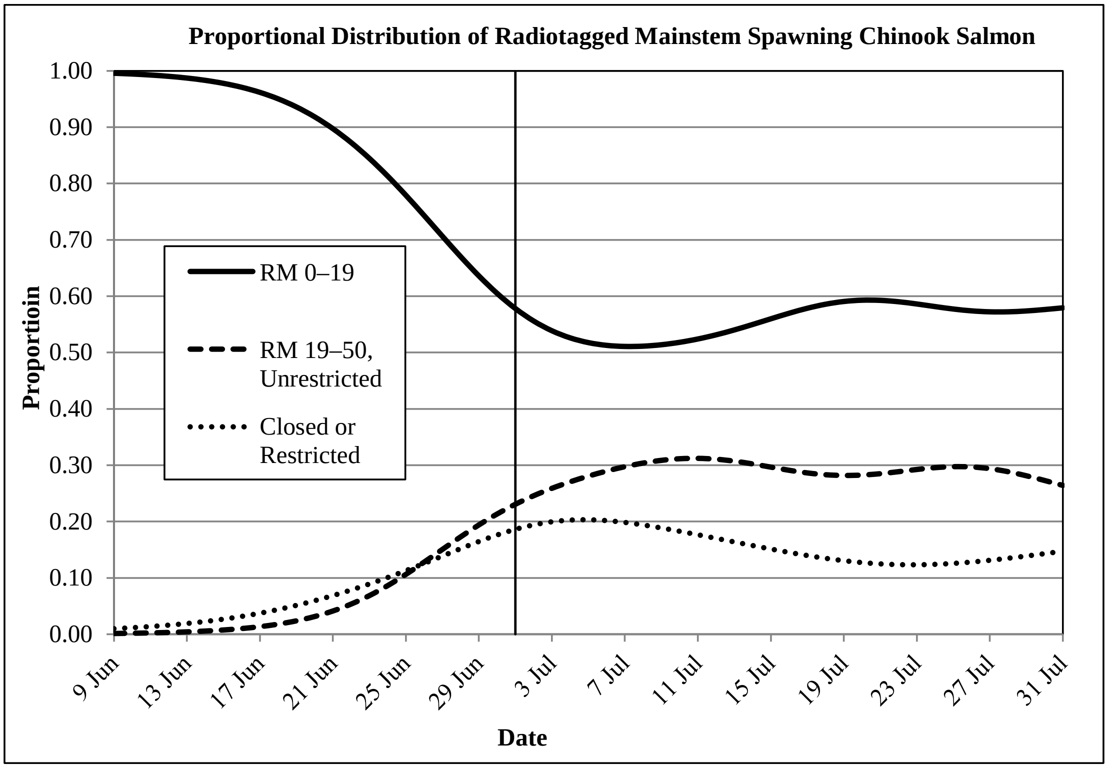

Figure 20.–Proportional distribution by date and area of radiotagged mainstem-spawning Kenai River Chinook salmon using a generalized additive model for 2012–2014.

Distribution by Spawning Destination

Tributary Spawners

Radiotagged Chinook salmon with tributary spawning destinations began migrating upstream of Slikok Creek in the second half of May and progressively entered closed or restricted fishing areas shortly thereafter (Figure 19). Tributary-spawning Chinook salmon upstream of Slikok Creek were mixed between waters with and without existing closures or restrictions through mid to late June, after which time the majority were in waters with existing closures or restrictions (Appendix D3, Figure 19). The highest proportion of tributary-spawning tagged fish upstream of Slikok Creek in unrestricted waters was in mid to late June. In July, tributary-spawning radio-tagged fish continued to migrate into closed or restricted waters while exiting both sections of the fishery (upstream and downstream of Slikok Creek). Almost all tributary-spawning Chinook salmon had exited waters open to sport fishing by the end of July (Figure 19).

Based on a generalized additive model for 2010–2014, the smoothed proportional distribution of tributary spawning Chinook salmon on 1 July was 8% (95% CI 7–9%) downstream of Slikok Creek, 23% (95% CI 21–25%) in unrestricted waters upstream of Slikok Creek, and 69% (95% CI 67–71%) in closed or restricted waters upstream of Slikok Creek (Appendix D3). On 15 July the smoothed proportional distribution of tributary spawning Chinook salmon was 0% (95% CI 0–1%) downstream of Slikok Creek, 5% (95% CI 4–6%) in unrestricted waters upstream of Slikok Creek, and 95% (95% CI 94–96%) in closed or restricted waters upstream of Slikok Creek (Appendix D3).

Mainstem Spawners

Mainstem-spawning radiotagged Chinook salmon began migrating upstream of Slikok Creek in mid-June while small numbers entered closed or restricted fishing areas shortly thereafter (Figure 20). After the first week in July, the percentages of radiotagged mainstem-spawning fish in each management area varied only slightly (Figure 20). Based on a generalized additive model for 2010–2014, the smoothed proportional distribution of mainstem-spawning Chinook salmon on 1 July was 58% (95% CI 52–64%) downstream of Slikok Creek, 23% (95% CI 18–29%) in unrestricted waters upstream of Slikok Creek, and 19% (95% CI 15–23%) in closed or restricted waters upstream of Slikok Creek (Appendix D4). On 15 July, the smoothed proportional distribution of mainstem-spawning Chinook salmon was 56% (95% CI 52–60%) downstream of Slikok Creek, 30% (95% CI 26–34%) in unrestricted waters upstream of Slikok Creek, and 15% (95% CI 13–18%) in closed or restricted waters upstream of Slikok Creek (Appendix D4).

DISCUSSION

This report presents the results of a telemetry study on Kenai River Chinook salmon in 2014 and 2015 and includes an updated summary of results of this same study during 2010–2013, most of which are reported in Reimer (2013). Results are put in context with existing sport fishing regulations and historical distribution data (Burger et al. 1983; Bendock and Alexandersdottir 1990-1992; Hammarstrom et al. 1985; Reimer 2013). Spawning distributions estimated during 2010–2015 may have similar behavioral, size, and spawning destination biases as historical estimates, but were generally improved from earlier studies because sample sizes of radiotagged fish were larger, radiotracking was more frequent, radiotag technology was improved, and there was a better understanding of Kenai River Chinook salmon from previous studies. Older tagging studies estimated catch-and-release mortality within the sport fishery (Bendock and

Alexandersdottir 1990-1992) or identified spawning locations, areas and, timing of runs (Burger et al. 1983; Hammarstrom et al. 1985). Recent radiotag deployments were generally designed to augment abundance estimation, particularly using genetics (Reimer et al. 2016); however, spawning distribution as well as other parameters such as stream life, site fidelity, spawning period, and inriver distributional data could be determined due to the frequency of boat tracking, aerial surveys, and numerous fixed telemetry stations. Broadly similar results were found in past studies despite differences in methods and objectives; however, past studies did not discern migratory or distributional patterns between tributary- and mainstem-spawning fish to the degree of the 2010–2015 studies for reasons stated above.

Nearly all the run timing information from these recent radiotelemetry studies corroborate well with entry patterns of Kenai River Chinook salmon using genetic stock identification techniques (McKinley et al. 2013; Reimer et al. 2016). Killey River and Benjamin Creek fish were the predominate stocks entering in May and from early to mid-June for both the radiotelemetry and genetic studies. Both radiotelemetry and genetic studies also indicate that Funny River fish primarily enter the river in June. Nearly all fish radiotagged in July in this study were mainstem spawners, similar to results from genetic studies. One difference between the radiotelemetry and genetic results is that genetic analyses indicate Russian River and Grant Creek fish primarily enter the river from mid-June to mid-July whereas during the radiotagging study, fish from those stocks were only radiotagged during 22–30 June. This discrepancy is probably because there was a low sample size of radiotagged fish in early-mid July from a lower tagging rate.

SIZE AND SPAWNING DESTINATION BIAS

If fish length influences spawning destination results, it is likely that tributary spawning destination estimates are biased because radiotagged migrants were length biased on samples that could be tested. We attempted to minimize this length bias by incorporating both nearshore and midriver sets equally in the inriver gillnetting protocol starting in 2014. Length distributions of radiotagged fish were not significantly different from the length distributions of all fish that passed each tributary weir in 2014 (Perschbacher and Eskelin 2016). However in 2015, tagged Killey River fish were significantly larger than those sampled at the weir (Table 11). Differences between length distributions are mostly because smaller fish were underrepresented in the inriver gillnet catches and radiotagged Chinook salmon less than 600 mm METF had lower survival than larger radiotagged fish.

We can also directly assess the bias of our 2012–2015 spawning destination estimates by comparing the ratio of radiotagged Funny River and Killey River fish that migrated past each weir to Funny River to Killey River weir passage for each year (Table 12). The proportion of fish that passed each weir that were radiotagged were similar for each year except for 2015, in which Funny River fish were underrepresented in the radiotagged sample compared to Killey River fish passed the weir. The lower tag deployment rate (1 of 3 captured fish) during 5–22 June 2015, compared to the remainder of 2015 when tags were deployed in all fish would likely explain the underrepresentation of Funny River radiotagged fish in 2015 because the lower tag deployment rate occurred during the peak passage of Funny River Chinook salmon past the tagging area as shown by radiotag results in Reimer (2013) and by genetic stock identification information in Reimer et al. (2016). However, when expanding to account for a lower tag deployment rate, the difference between the proportions increased. This discrepancy may be due to low sample size of radiotagged fish, especially in the Funny River, or due to sample size differences in fish bound for each tributary relative to the RM 8.6 sample. The higher proportion of radiotagged fish compared to weir passage that was observed in 2014 compared to other years was because netting effort in 2014 was doubled compared to other years.

Bias in the determination of mainstem spawning destinations is probably similar to the bias in determining tributary spawning destinations, especially if this bias is due to differences in the length of radiotagged fish with a determined spawning destination versus all fish. We are able to directly assess sampling bias in composition of tributary spawners because weirs on the Killey River and Funny River provide passage and length information to compare with tagged fish. However, there is no way to directly assess bias in the composition of mainstem spawners so we can only assume that a similar sampling bias toward larger fish exists.

BIAS IN MIGRATORY TIMING ESTIMATES

Migratory timing estimates could be biased due to migratory delays from handling. The severity of this bias was assessed by comparing the timing of radiotagged Chinook salmon that passed the Funny and Killey river weirs to all Chinook salmon that passed each weir (Figures 21 and 22). Date of entry into the Funny River was used as a surrogate for date past the Funny River weir because the Funny River weir was located approximately 1.6 RM upstream of the confluence with the Kenai River. A fixed telemetry station was located at the Killey River weir so date of passage of radiotagged fish past the Killey River weir is represented accurately.

Radiotagged Chinook salmon did not show a systematic bias towards later migration (Figures 21 and 22). In 2014, radiotagged fish passed each weir later than all fish that passed at each weir but migratory timing was similar for radiotagged fish and all fish in most other years. In 2015, radiotagged fish passed the Funny River weir earlier than the run timing of all fish past the weir. This may be due to tagging a higher proportion of Funny River bound fish earlier in the run than later in the run when the tag deployment rate was decreased; however, radiotagged Killey River fish were not systematically earlier than the run timing of all fish past the Killey River weir in 2015.

KILLEY RIVER ABUNDANCE ESTIMATES

Sources of bias attributable to spawning destination estimates mentioned previously could also affect Killey River abundance estimates (Table 9) because radiotagged Chinook salmon that passed the Killey River weir were significantly larger than untagged fish that passed the weir during 3 of 4 years (Figure 7). The size of radiotagged fish above and below the weir was not significantly different for any year (Figure 5 and Table 10); however, because the sample of radiotagged fish upstream of the weir is biased towards larger fish, the sample of radiotagged fish downstream of the weir is probably also biased towards larger fish, which means the spatial distribution of the smaller fish in the run cannot be assessed. Smaller-sized fish have composed a large percentage of Killey River weir passage since 2013, especially fish within the 500 mm to 650 mm METF length range (Gates and Boersma 2013, 2014a, 2014c, 2016) The average METF lengths of sampled fish in the Killey River were 804 mm, 650 mm, 696 mm, and 699 mm in 2012–2015, respectively. If smaller fish are more likely to migrate upstream of the weir, the Killey River escapement estimates based on weir passage and radiotelemetry would be biased and low, whereas if small fish were more likely to remain below the weir, the escapement estimates would still be biased but high.

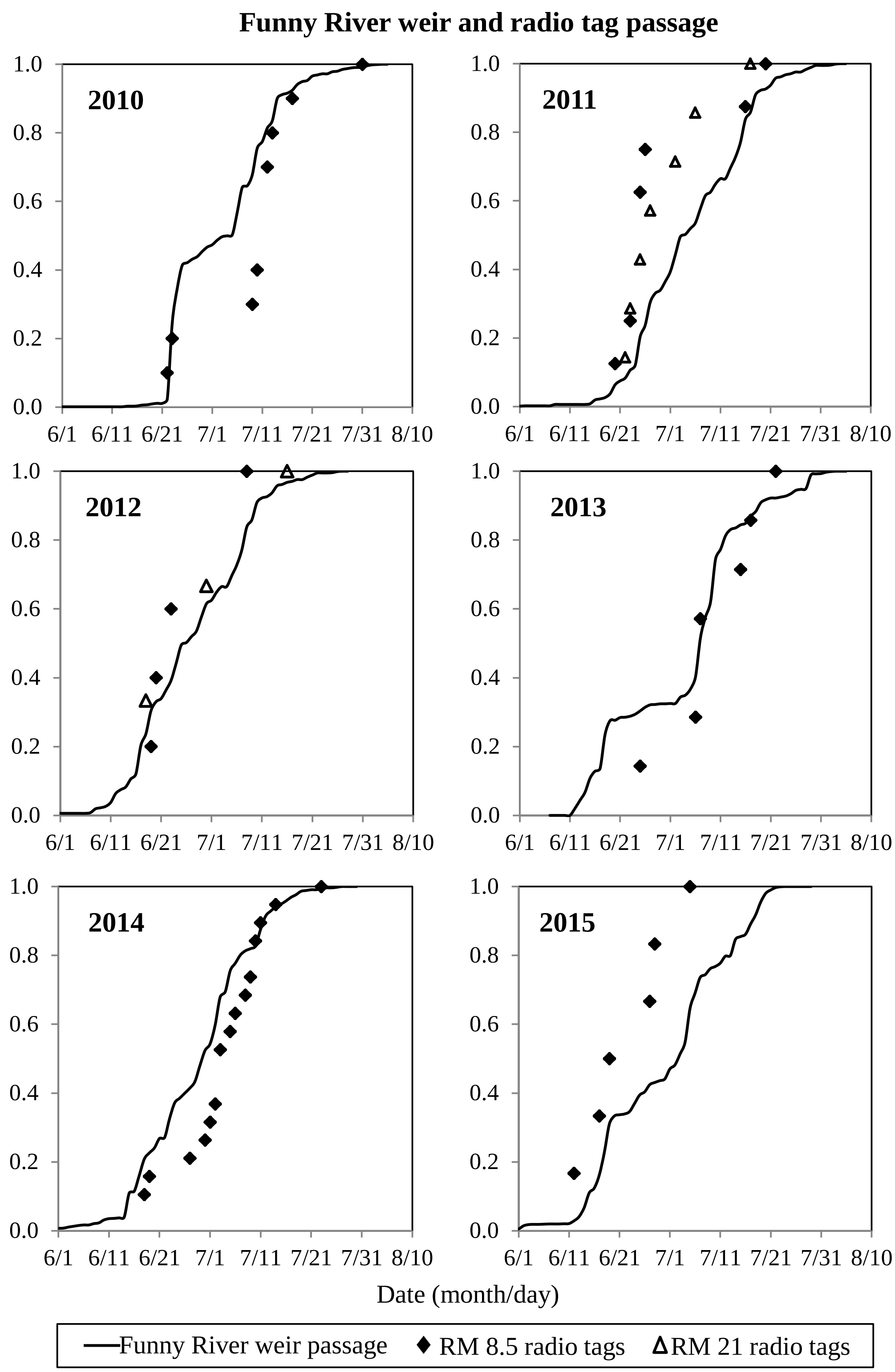

Figure 21.–Cumulative proportion by date of migration past the Funny River weir for radiotagged Chinook salmon and all Chinook salmon, 2010–2015.

Note: Funny River weir passage data provided by USFWS (Gates and Boersma 2011, 2014b; Boersma and Gates 2013, 2014, 2016).

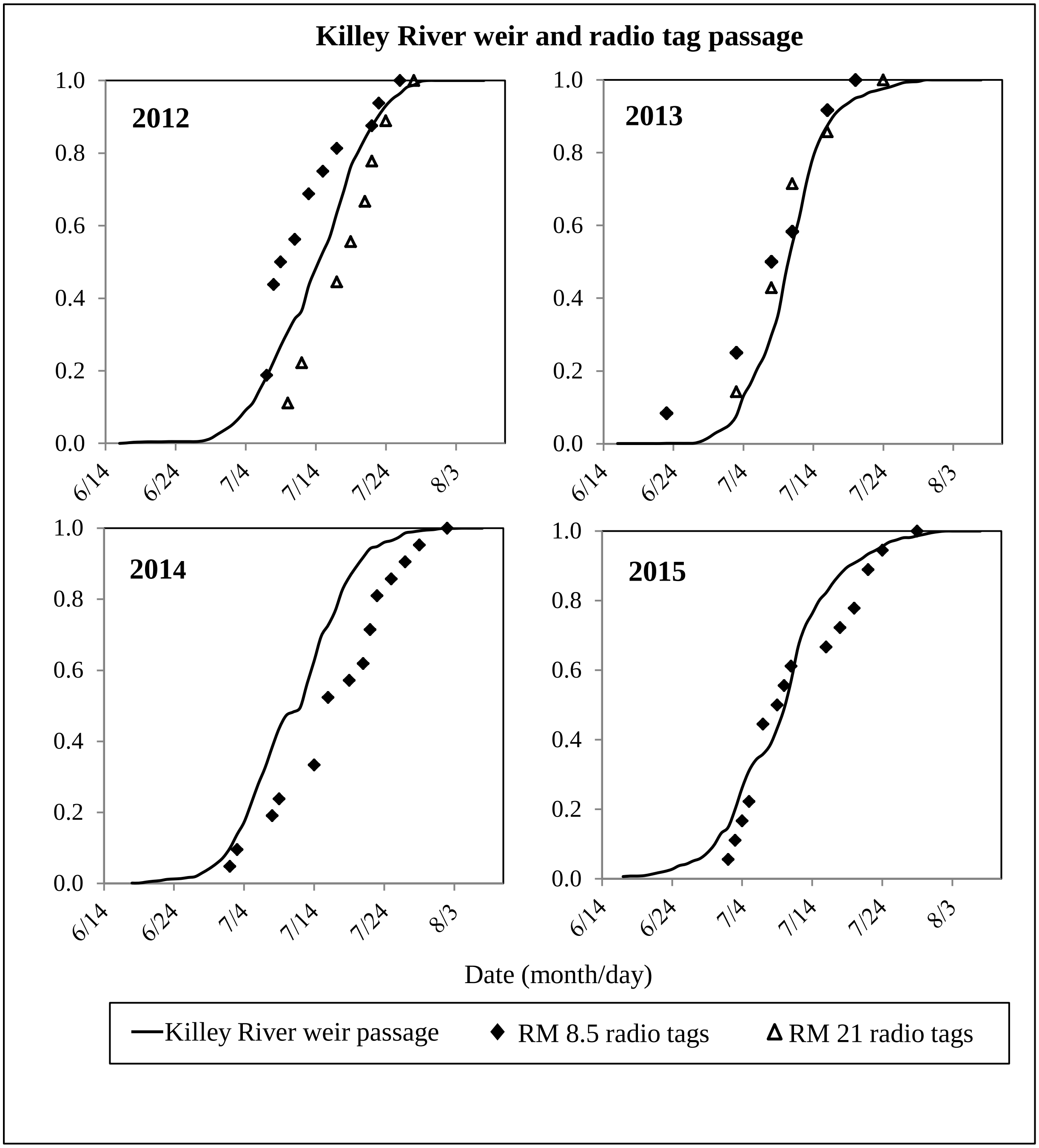

Figure 22.–Cumulative proportion by date of Chinook salmon passage at the Killey River weir for radiotagged Chinook salmon and all Chinook salmon, 2012–2015.

Note: Killey River weir passage data provided by USFWS (Gates and Boersma 2013, 2014a, 2014c, 2016).

The 2012 estimate of Killey river abundance using weir passage and radiotag distribution within the Killey River drainage relative to the weir (3,934 SE 627) was very similar to the 2012 estimate using genetics (4,124 SE 530) (Reimer et al. 2016). Killey River weir passage in 2015 was the highest of any year since it was first installed in 2012; however the increase in weir counts was not reflected in the 2015 Killey River escapement estimate due to the larger percentage of radiotagged Killey River migrants spawning upstream of the Killey River weir than in previous years (Table 8). Sixty-four percent of radiotagged fish that entered the Killey River in 2015 migrated upstream of the weir whereas that percentage was about 40–50% during previous years (Table 8). Only 28 radiotagged fish migrated to the Killey River in 2015, which was considerably less than other years due to a lower number of total tags deployed. There are a number of potential biases that could affect the Killey River escapement estimates, including size biases mentioned above. However, the lower sample size of radiotagged fish entering the Killey River in 2015, should be taken into account when evaluating the 2015 Killey River escapement estimate.

It is also noted that radiotagged Chinook salmon distribution within the Killey River drainage relative to Benjamin Creek varied drastically in the 1990 and 1991 studies (Bendock and Alexandersdottir 1992). In 1990, 4 of the 43 (9%) radiotagged Chinook salmon that entered the Killey River were determined to have spawned in Benjamin Creek. In 1991, 21 of the 49 (43%) radiotagged Chinook salmon that entered the Killey River were determined to have spawned in Benjamin Creek (Table 15; Bendock and Alexandersdottir 1992). Although there were probably differences in how each of these studies were conducted, the results from the earlier 1990 and 1991 studies and the recent 2010–2015 studies suggest that distribution within the Killey River drainage can be highly variable.

Killey River Hydrology

Reimer (2013) noted that the amount of spawning habitat available within Benjamin Creek has been variable and probably affects productivity. There are 2 forks that discharge into the Killey River. The northern fork contains substantially more quality spawning habitat compared to the southern fork. In 2005 and 2006, nearly all of the water flowed through the northern fork; however, when the site was revisited in 2011, nearly all the water flowed through the southern fork with very little water in the northern fork for Chinook salmon to spawn. After 2013, streamflow was split about evenly between each fork. It is unclear how productivity is affected with varying water levels in each fork, but productivity probably decreases in Benjamin Creek when discharge through the northern fork prevents Chinook salmon from spawning in that area.

Similar to Benjamin Creek, the Killey River drains into the Kenai River via multiple forks (lower, middle, and upper) and the lower and middle forks have experienced dynamic changes in relative discharge. Prior to 2010, most discharge had occurred through the lower fork, but in 2010 a major logjam formed in the lower fork and diverted most of the discharge through the middle fork. In 2013, discharge began to increase in the lower fork and by 2015 most discharge occurred through the lower fork. Recent (2010–2015) radiotagging data indicate that most spawning within the Killey River drainage occurs upstream of the split between the lower and middle forks so it is doubtful that the hydrological changes have affected productivity appreciably. Discharge through the upper fork is negligible and no radiotagged Chinook salmon have been tracked in the upper fork during any year.

EARLY-RUN AND TRIBUTARY SPAWNING COMPOSITION AND DISTRIBUTION

Radiotagged Chinook salmon with a spawning destination in the Killey River drainage (including Benjamin Creek) were the largest component of the early run in all datasets (Bendock and Alexandersdottir 1992; Burger et al. 1983,1985; Reimer 2013). Mainstem spawners were the second largest contributor of the early run in 4 of 5 recent years (2010–2014 [Reimer 2013], Table 6) and were the second or third largest contributor to the early run in the older studies (Bendock and Alexandersdottir 1992; Burger et al. 1985). Funny River spawners were the third largest contributor to the early run in 4 of 5 recent years, the second largest contributor in the other recent year (2010–2013 [Reimer 2013], Table 6), and the second or third largest contributor to the early run in the older studies (Bendock and Alexanderdottir 1992, Burger et al. 1985).

The spawning contribution of all other tributary spawners was minor. No Killey River, Benjamin Creek, or Funny River fish were tagged in July during any recent year (Table 16), whereas Juneau Creek and Quartz Creek each had one fish tagged in July (Table 17). However, July migration of minor tributary stocks may be underrepresented because of the lower tagging rate that occurred in July. For example, the unaffiliated genetic modeling effort indicated more Grant Creek and Russian River fish return in July than June (Reimer et al. 2016). In one of the older studies (Bendock and Alexandersdottir 1992), single fish bound for Slikok Creek, Funny River, Benjamin Creek, Russian River, and Juneau Creek were tagged in July during the late run although those fish were sport caught and tagged upstream of RM 8.6 and thus may have entered in June.

Mainstem spawners made up 15% (SE 5%) to 28% (SE 5%) and averaged 21% (SE 3%) of the early run during the recent 2010–2014 studies (Table 15). The relative contribution of mainstem-spawning Chinook salmon to the early run during 2010–2014 was within the range observed in 1990 (30%, SE 6%) and 1991 (9%, SE 3%); however, the relative contribution was greater than in 1980 (0%, SE 0%) and 1981 (5%, SE 5%) (Table 15). Although the estimated abundance of early-run Kenai River Chinook salmon was below average during 2010–2014, (Begich et al. 2017) the proportion of mainstem-spawning fish that entered the river during the early run is similar in both the historical (1990 and 1991) and recent (2010–2014) studies (Table 15).

MAINSTEM SPAWNING DESTINATIONS

The determination of mainstem spawning destinations from radiotelemetry is more difficult than determining tributary spawning destinations. Censoring criteria used during 2010–2015 were based on minimum requirements for determining whether a fish spawned or not. Because the Kenai River is deep and glacially occluded, spawning was not observed. As a result, some fish may have been incorrectly classified as spawners if "holding" patterns observed from radiotracking were not due to spawning. While data from tagged fish are subject to misclassifying censored fish, the recent data (2010–2015) benefits from several programmatic advantages over the older studies. First, the recent studies captured and released tagged fish farther downstream from mainstem spawning areas so fish had to better "prove" vitality by migrating further upstream after tagging. Second, fish were located by radiotracking more frequently and in more locations, allowing for more spatial and temporal resolution to better determine holding patterns and assign spawning destinations. Finally, tags were implanted, reducing the latent tagging effects known to be associated with externally mounted radiotags used in some older studies (Reimer and Fleischman 2012).

Mainstem spawning destinations determined from the radiotagging studies in 2010–2014 are illustrated in Appendices A1–A7. Spawning destinations depicted in Appendices A1–A7 are approximate and are not intended to provide exact spawning locations because it was not possible to observe actual spawning. While mainstem spawning Chinook salmon were distributed throughout the Kenai River (Figures 8 and 10), several areas had higher densities of radiotagged spawners. Nearly the entire lower river from RM 12.8 to RM 21 had high numbers of spawners and also a smaller area within the Kenai National Wildlife Refuge between RM 46.1 and RM 46.4 was densely populated (Figure 10, Appendix A5). When the 2012–2014 data are summarized by geographic area, the area downstream of the Soldotna Bridge had the greatest number and density of mainstem spawners every year (38% of total radiotagged mainstem spawners on average), followed by the area between Moose River confluence and Skilak Lake outlet (average 28%), Soldotna Bridge to Moose River confluence (average 21%), and lastly Skilak Lake inlet to Kenai Lake outlet (average 12%) (Table 13). When comparing these percentages by geographic area to older tagging studies (Burger et al. 1983; Hammarstrom et al. 1985; Bendock and Alexandersdottir 1992), the distribution by area is very similar (Table 13). Furthermore, the 2012–2014 distribution of radiotagged mainstem spawners that arrived during the early run was similar to those that arrived in the late run (Figure 11), suggesting that mainstem spawning destinations are mostly unrelated to run timing.

RUN TIMING IN RELATION TO CHINOOK SALMON MANAGEMENT

Sport fishing during the early run was closed by emergency order during 2013–2015. Along with the sport fishing closure during the early run, the area upstream of Slikok Creek was also closed to fishing throughout the late run to "follow the fish" and protect tributary spawners as they migrated to their natal streams. Based on radiotelemetry results, the inseason closures upstream of the Slikok Creek have been an effective conservation measure because nearly all (>90%) radiotagged tributary spawning fish were in protected waters when the late-run fishery began on 1 July (Figure 19). By 9 July, more than 90% of tributary spawners were in waters with existing closures or restrictions (Figure 19). Thus, existing regulations that prohibit sport fishing in closed or restricted areas upstream of Slikok Creek provide the primary protection for tributary spawners; inseason closures or bait restrictions upstream of Slikok Creek provide only modest additional protection because fish are generally already in closed or restricted areas by regulation.

Radiotagged Chinook salmon returning to minor tributaries such as those in the upper Kenai River (Russian River, Juneau Creek, Quartz Creek, and Grant Creek) benefit from restrictions upstream of Slikok Creek but since these tributaries support relatively low numbers of spawning fish, the numbers of radiotagged fish migrating to these locations was also low during each year of the study. Consequently, information about the run timing and distribution of radiotagged fish returning to minor tributaries is limited by very small sample sizes.

The sanctuary areas closed to fishing around the mouths of Slikok Creek, Funny River, and Killey River protect Chinook salmon throughout the entire fishing season because fish usually "stage" (hold in place for a period of time) prior to entering the spawning tributary. These sanctuary areas were closed to Chinook salmon fishing through 14 July during 1993–2007 and have been closed through the end of July since 2008. The highest densities of radiotagged fish noted in the Funny River and Killey River closed areas occurred during late June to early July. High densities of radiotagged fish were found throughout the entire Killey River sanctuary in all years, whereas in the Funny River sanctuary, the area immediately downstream of the Funny River confluence held the majority of staging Funny River fish. Only one Slikok Creek fish was tagged during 2010–2015 so information about the Slikok Creek sanctuary with respect to holding and timing of Slikok Creek fish is extremely limited.

The conservative existing regulations as well as inseason closures that prohibited Chinook salmon fishing upstream of Slikok Creek (EOs: 2-KS-18-12, 2-KS-1-24-13, 2-KS-1-36-13, 2-KS-1-04-14, 2-KS-1-26-14, 2-KS-1-05-15) also protected some mainstem spawners; however, the majority (>50%) of mainstem spawners in the river in July remained downstream of Slikok Creek (in unrestricted waters) (Figure 20) and these data do not include fish that returned to the river in August. On 1 July, 23% of radiotagged mainstem spawners that were in the Kenai River were upstream of Slikok Creek sanctuary in unrestricted waters. That percentage rose to 30% by 7 July and remained near 30% for the rest of July (Figure 20). The remaining 10–20% of mainstem spawners were in closed or restricted waters upstream of Slikok Creek (Figure 20). Thus, inseason restrictions upstream of Slikok Creek in July can provide modest protection to some mainstem spawners although the majority of mainstem spawners are either in the lower river or have not yet entered the river during July.

Most mainstem spawning occurs in August, well after the sport fishery closes. The median date for the beginning of site fidelity for all radiotagged mainstem spawners was 18 August (Table 18). It is likely that spawning generally occurs in mid to late August. Consequently, many mainstem spawners do not migrate to their spawning destination until after the fishery closes. A comparison was made between the location of radiotagged mainstem spawners at the end of the sport fishery and their eventual spawning location (Figures 23–26) or spawning area (Table 20). Many fish were downstream of their eventual spawning area at the end of July. For example, only 11 out of 59 radiotagged fish (19%) that spawned between Moose River confluence and Skilak Lake outlet were located within that same section of river at the end of the sport fishery on July 31 (Table 20). The remaining 81% of these fishwere either downstream of the Moose River confluence or hadn't been captured yet in the inriver gillnetting program at RM 8.6 (Table 20). However, there were also 8 other radiotagged fish in the section between Moose River confluence and Skilak Lake at the end of July. These fish eventually spawned in the upper river between Skilak Lake and Kenai Lake, representing 36% of all radiotagged fish that spawned within that section (Table 20).

It is important to understand where migrating spawners are located when the fishery closes in order to evaluate the impact of potential conservation measures. Conservation measures that target fish that spawn in a specific river section will not benefit completely by restricting harvest in the same river section because many of those fish are downstream of the target area during the fishery (Table 20). The effectiveness of this type of conservation measure also decreases the farther the targeted river section is located upstream (note numbers highlighted in grey in Table 20). In addition, targeting upstream areas for conservation during the late run will essentially have no conservation value for fish that spawn in areas downstream of the river section of interest. Thus, conservation measures proposed for upstream river sections will affect smaller portions of the fish spawning in the proposed area and offer little ancillary benefit to fish spawning in downstream areas. Conversely, protective measures proposed for downstream river sections will not only protect more fish that spawn in the proposed conservation area but will also protect fish that spawn upstream of the targeted area because most fish do not migrate quickly to the mainstem river sections where they spawn in August (after the fishery closes).

Inriver migration through the mainstem is protracted and many fish have not migrated upstream to their eventual spawning area by the end of July. Hence, findings from this telemetry project show that inriver spatial distribution of mainstem-spawning Chinook salmon during the sport fishery is skewed towards more downstream areas than the spatial distribution of Chinook salmon spawning locations, and that spawning location appears to be mostly unrelated to time of entry (Table 18).

Inriver harvest of Chinook salmon in proportion to run timing and abundance is a management issue for both mainstem- and tributary-spawning fish. One of the important management concerns is the overexploitation of mainstem-spawning fish that enter the Kenai River prior to 1 July. By virtue of run timing, the earliest returning mainstem-spawning fish may be available to the sport fishery for a longer period of time than later returning mainstem spawners if they remain in unrestricted waters prior to spawning. On the other hand, the latest returning mainstem-spawning fish are not exposed to a directed sport fishery if they enter the river in August. Although this report does not include studies designed to address exploitation of Kenai River Chinook salmon stocks and therefore does not include any review of exploitation, the fish distributions determined from this report could be used in combination with information from several other projects that address the genetic composition of Kenai River Chinook salmon harvests in various fisheries (McKinley et al. 2013; Eskelin and Barclay. 2015; Reimer et al. 2016; Perschbacher and Eskelin 2016) to review the exploitation of mainstem-spawning Chinook salmon relative to run timing, size, and abundance.

Recent radiotelemetry studies during 2010–2015 have provided and will continue to provide useful information for managers and the Alaska Board of Fisheries in developing or modifying fishing regulations. In this recent update, we have 6 years of early-run spawning distribution information and 3 years of late-run spawning distribution information when fish were radiotagged during the entire late run. These radiotelemetry studies were conducted during a time of historically low abundance (Begich et al. 2017) and young average age at maturity (Perschbacher and Eskelin 2016); therefore, it would be beneficial to conduct a similar study when productivity rebounds.

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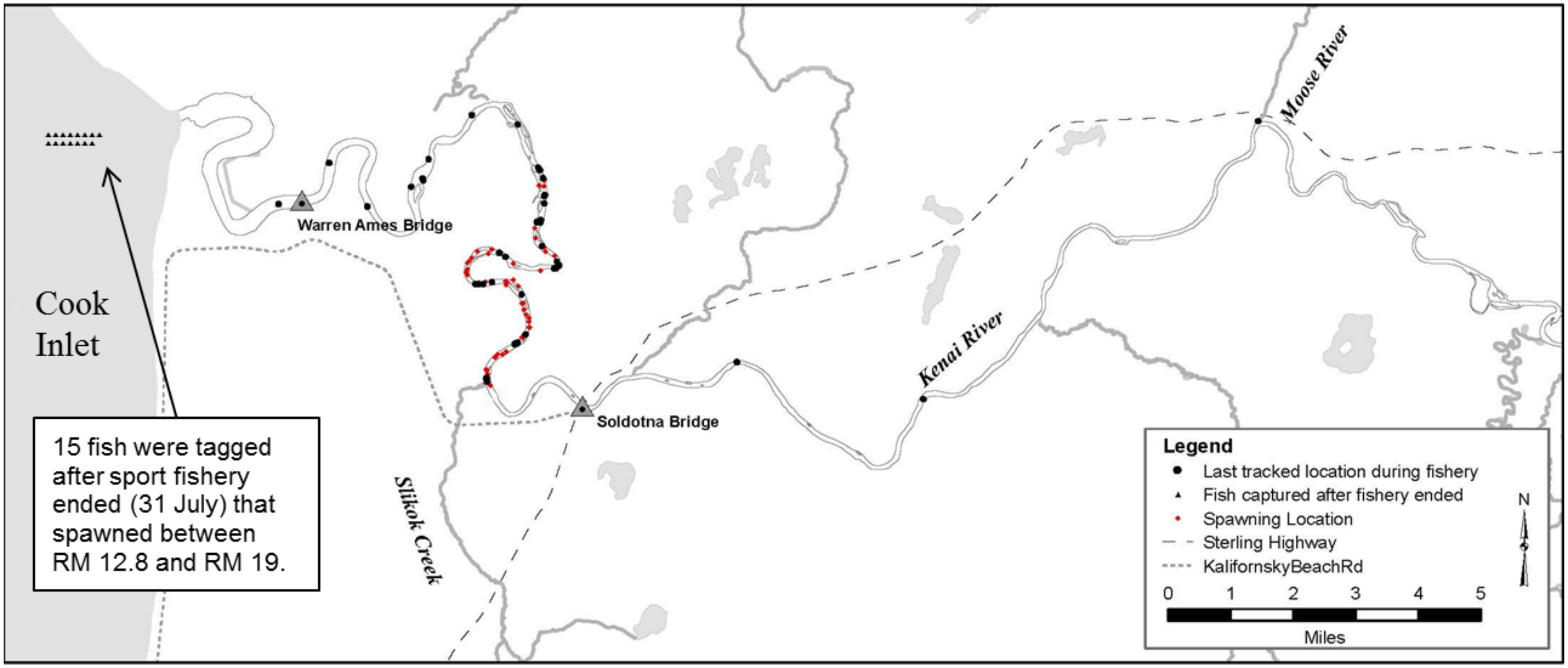

Figure 23.–The locations of Chinook salmon radiotagged during 2010–2014 that eventually spawned between RM 12.8 and Slikok Creek (RM 19) are shown for July 31 at the end of the sport fishery (either prior to radiotagging in August [black triangles] or last-tracked location [black circles] of those radiotagged earlier) and for their final spawning locations (red circles).

Note: There were 15 fish radiotagged after the sport fishery ended (July 31) that also spawned between RM 12.8 and RM 19. These fish are included in the spawning location data but not the last-tracked data.

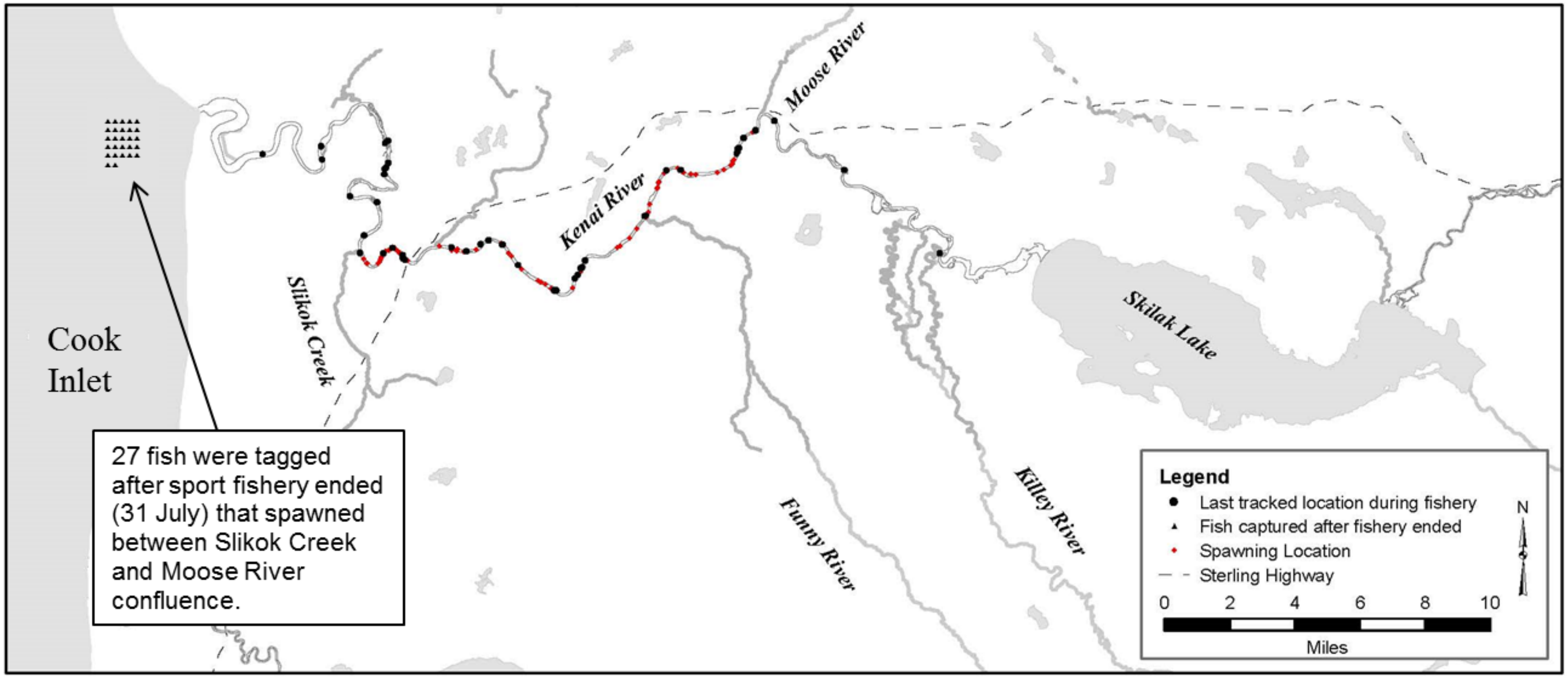

Figure 24.–The locations of Chinook salmon radiotagged during 2010–2015 that eventually spawned between the Slikok Creek and Moose River confluences are shown for July 31 at the end of the sport fishery (either prior to radiotagging in August [black triangles] or last-tracked location [black circles] of those radiotagged earlier) and for their final spawning locations (red circles).

Note: There were 27 fish radiotagged after the sport fishery ended (July 31) that also spawned between the Slikok Creek and Moose River confluences. These fish are included in the spawning location data but not the last-tracked data.

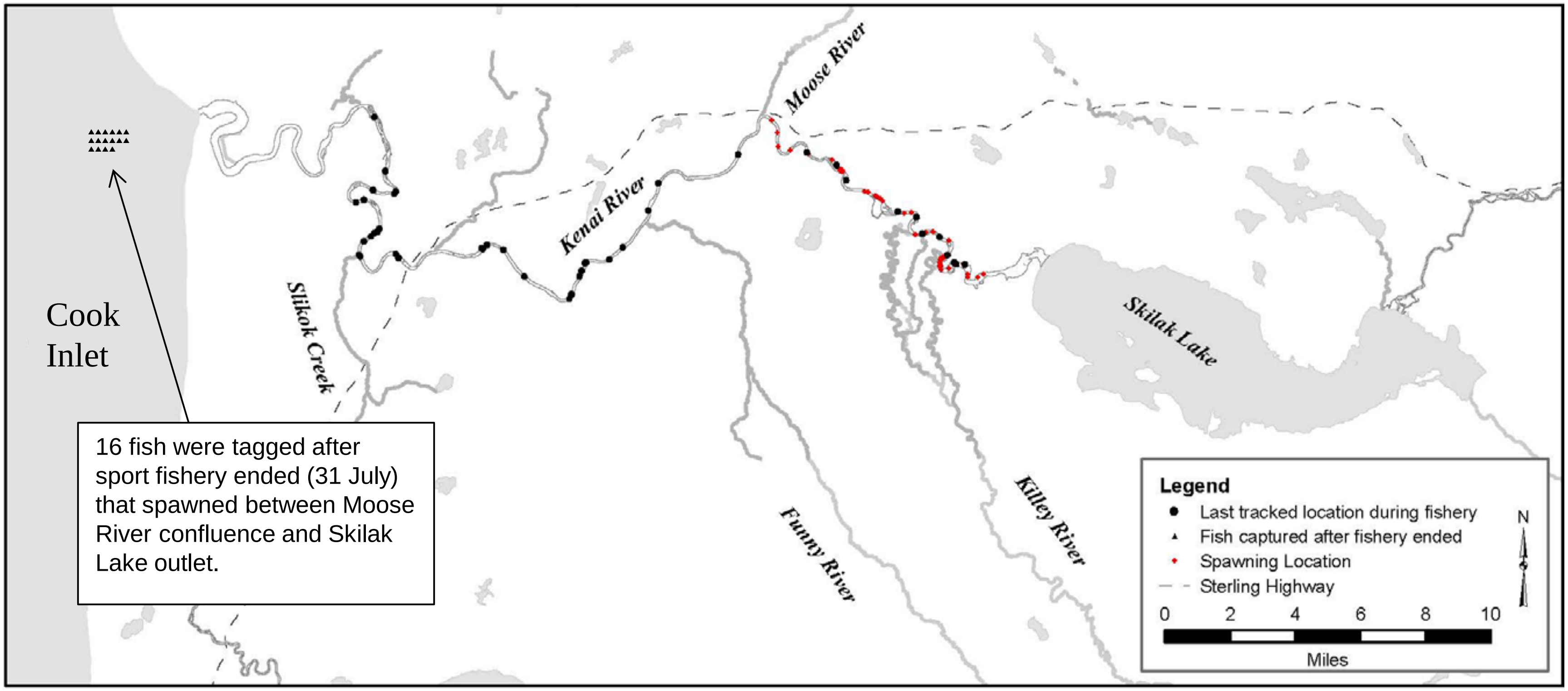

Figure 25.–The locations of Chinook salmon radiotagged during 2010–2015 that eventually spawned between the Moose River confluence and Skilak Lake outlet are shown for July 31 at the end of the sport fishery (either prior to radiotagging in August [black triangles] or last-tracked location [black circles] of those radiotagged earlier) and for their final spawning locations (red circles).

Note: There were 16 fish radiotagged after the sport fishery ended (July 31) that also spawned the Moose River confluence and Skilak Lake outlet. These fish are included in the spawning location data but not the last-tracked data.

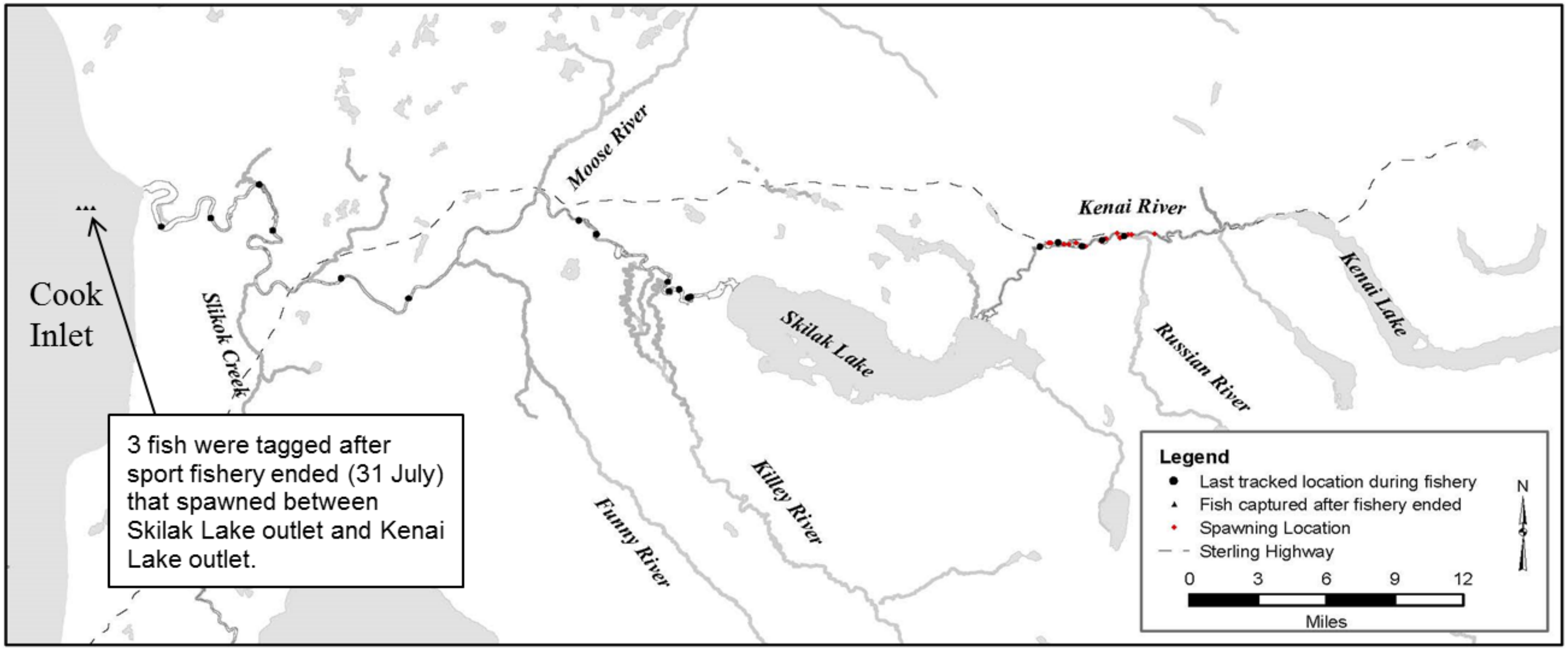

Figure 26.–The locations of Chinook salmon radiotagged during 2010–2015 that eventually spawned between Skilak Lake outlet and Kenai Lake outlet are shown for July 31 at the end of the sport fishery (either prior to radiotagging in August [black triangles] or last-tracked location [black circles] of those radiotagged earlier) and for their final spawning locations (red circles).

Note: There were 3 fish radiotagged after the sport fishery ended (July 31) that also spawned between Skilak Lake outlet and Kenai Lake outlet. These fish, shown in Cook Inlet, are included in the spawning location data but not the last-tracked data.

Table 20.–Numbers of radiotagged spawners (2010–2014) per mainstem spawning area and locations of these mainstem-spawning Chinook salmon near the end of the inriver sport fishery.

Mainstem spawning area	Total number of radiotagged spawners tracked near end of sport fishery or captured after fishery ended	Location of Chinook salmon near the end of sport fishery				
		Downstream of RM 8.6 or in Cook Inlet [a]	Downstream of Slikok Creek	Slikok Creek to Moose River	Moose River to Skilak Lake	Skilak Lake to Kenai Lake
		No. (% total)	No. (% total)	No. (% total)	No. (% total)	No. (% total)
RM 12.8 to Slikok Creek	57	15 (26%)	39 (68%)	3 (5%)	0 (0%)	0 (0%)
Slikok Creek to Moose River	75	29 (39%)	13 (17%)	30 (40%)	3 (4%)	0 (0%)
Moose River to Skilak Lake	59	16 (27%)	12 (20%)	20 (34%)	11 (19%)	0 (0%)
Skilak Lake to Kenai Lake	22	3 (14%)	4 (18%)	2 (9%)	8 (36%)	5 (23%)
Total	213	63 (29%)	68 (32%)	55 (26%)	22 (10%)	5 (2%)

Note: Chinook salmon radiotagged before the end of July were only used for this table if the last tracked location was between 28 and 31 July each year.

[a] Number of fish that were in captured and radiotagged at RM 8.6 after the end of the sport fishery and tracked to their eventual spawning location.

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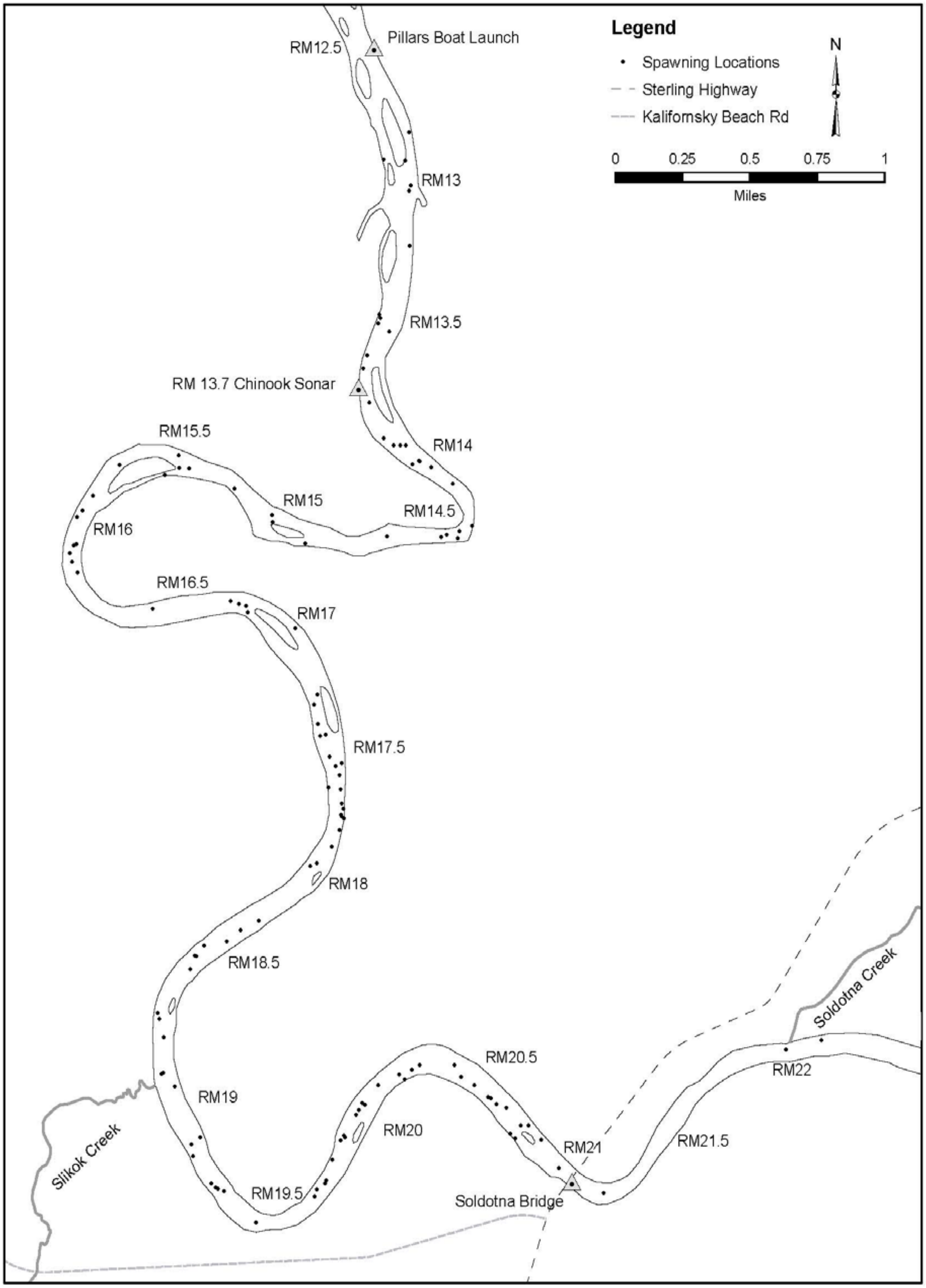
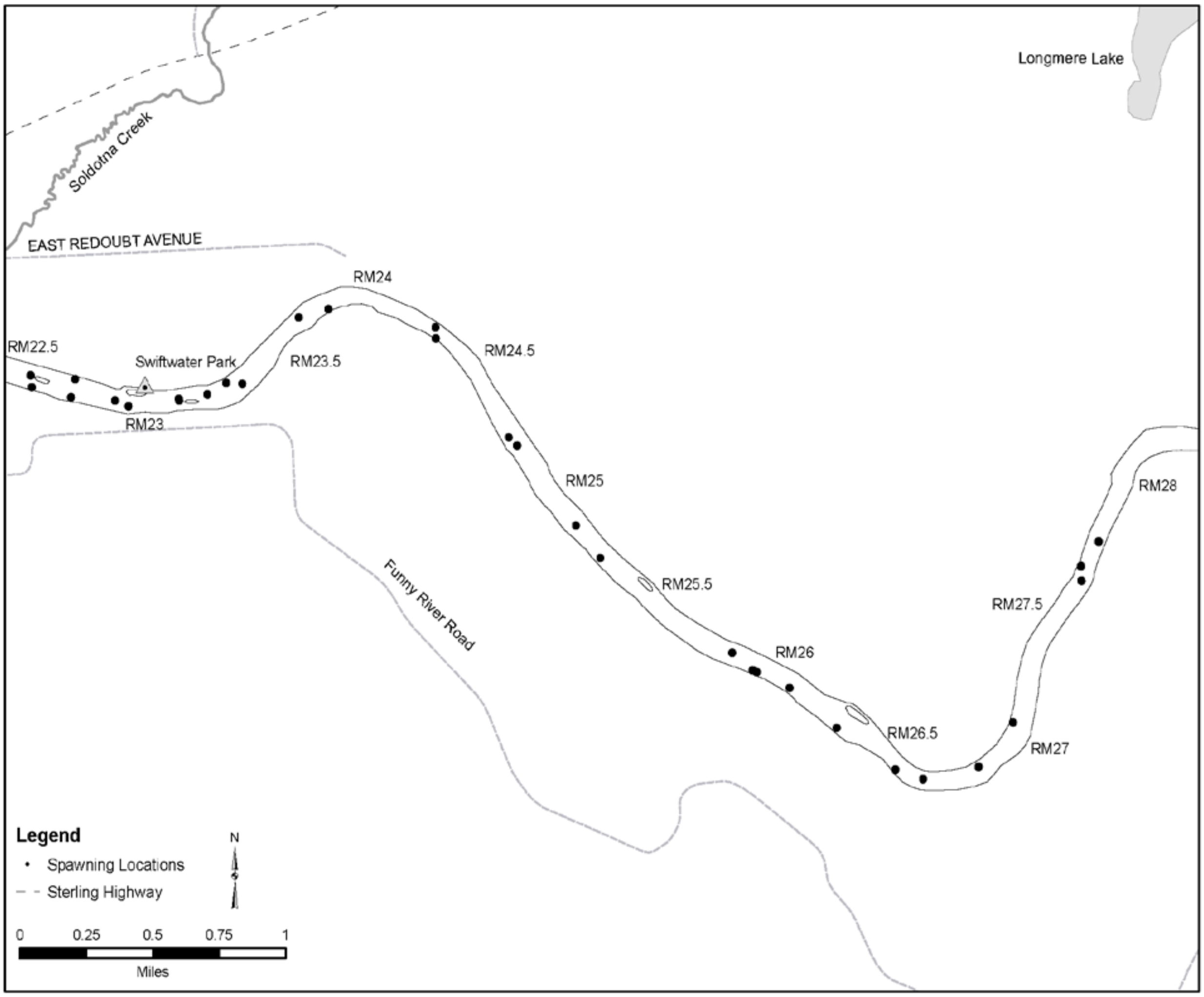
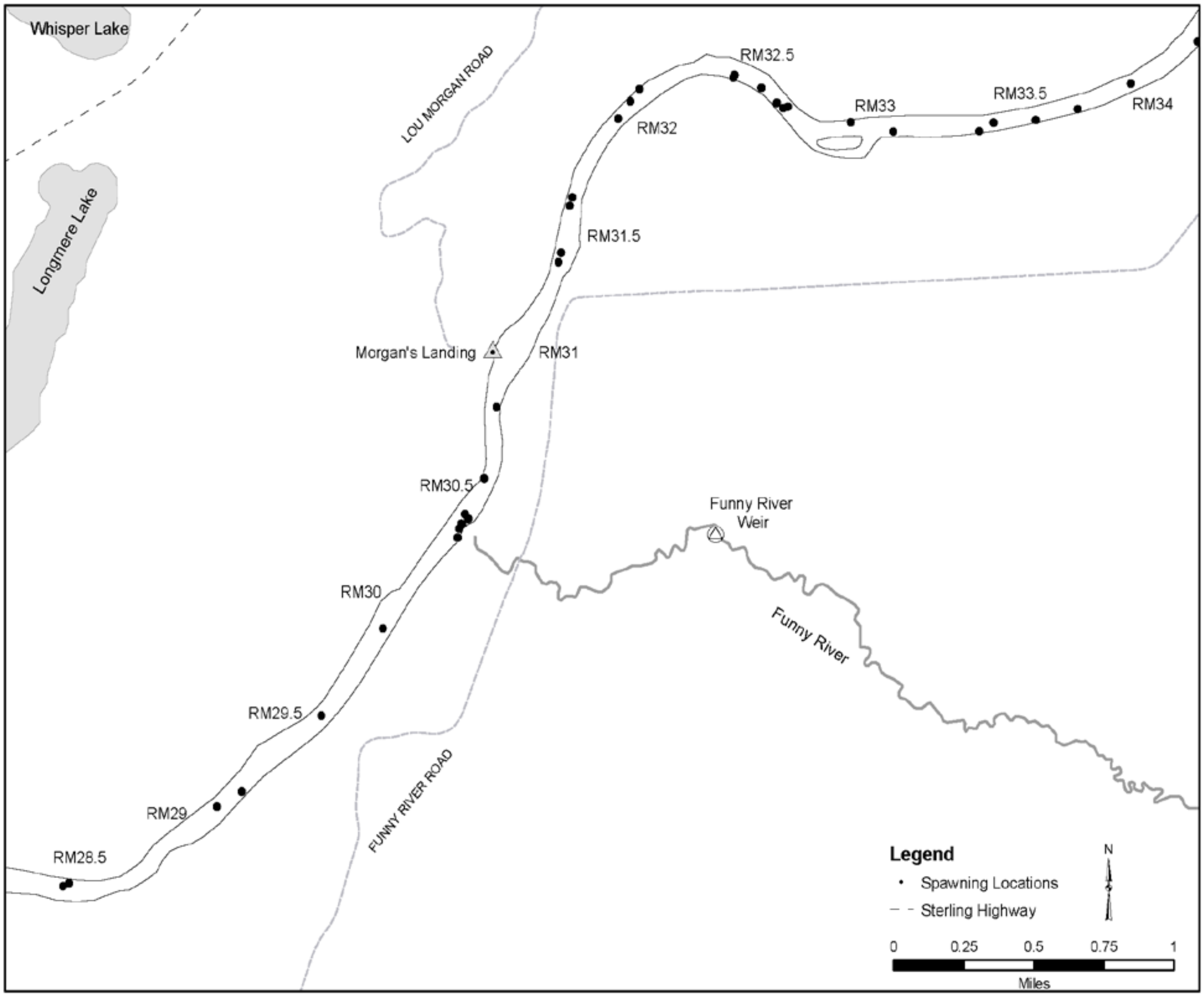
APPENDIX A: SPAWNING DESTINATIONS BY GEOGRAPHIC AREA FOR RADIOTAGGED CHINOOK SALMON WITHIN THE MAINSTEM KENAI RIVER



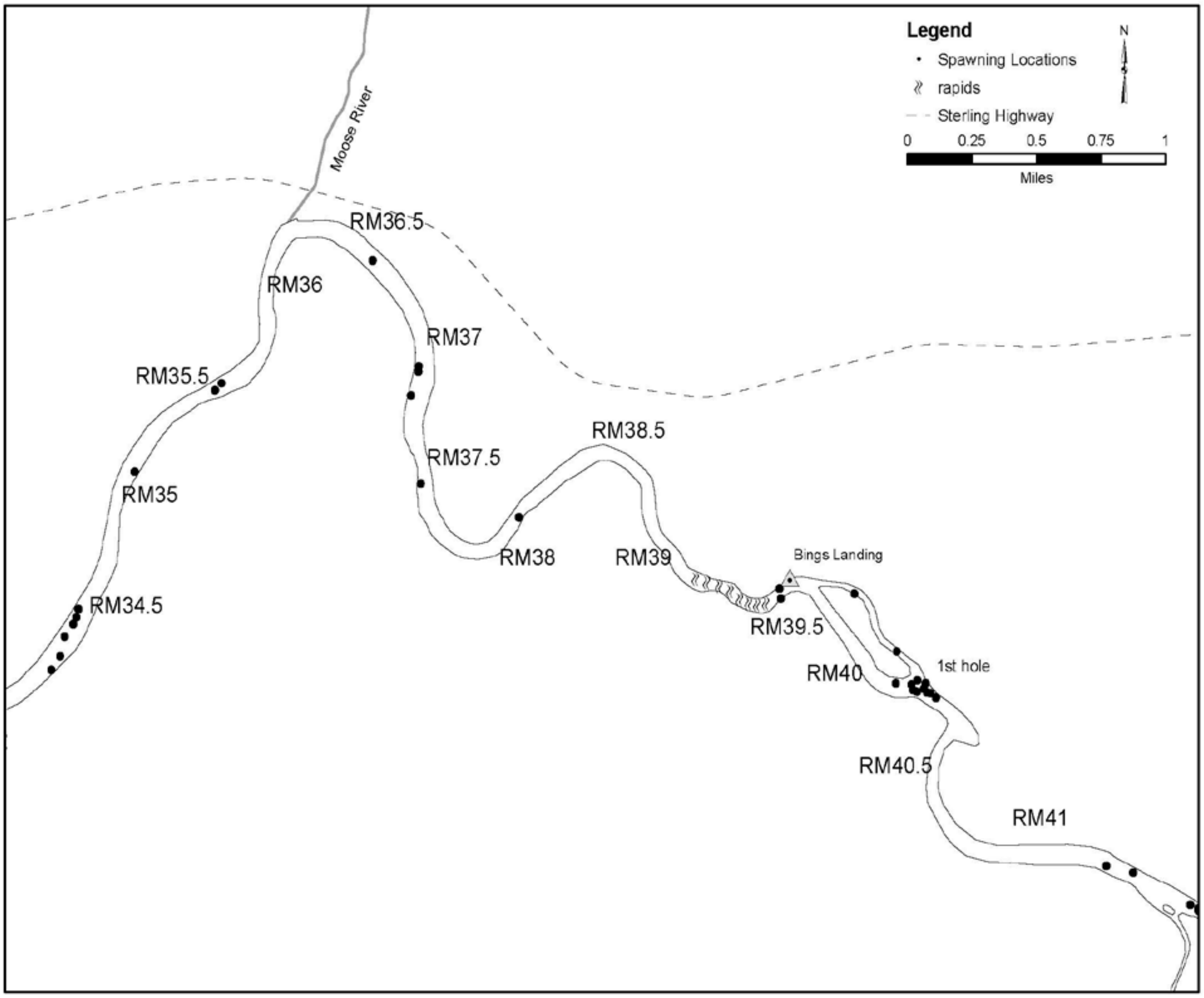
Appendix A1.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 12.8 and RM 22.3, 2010–2014.



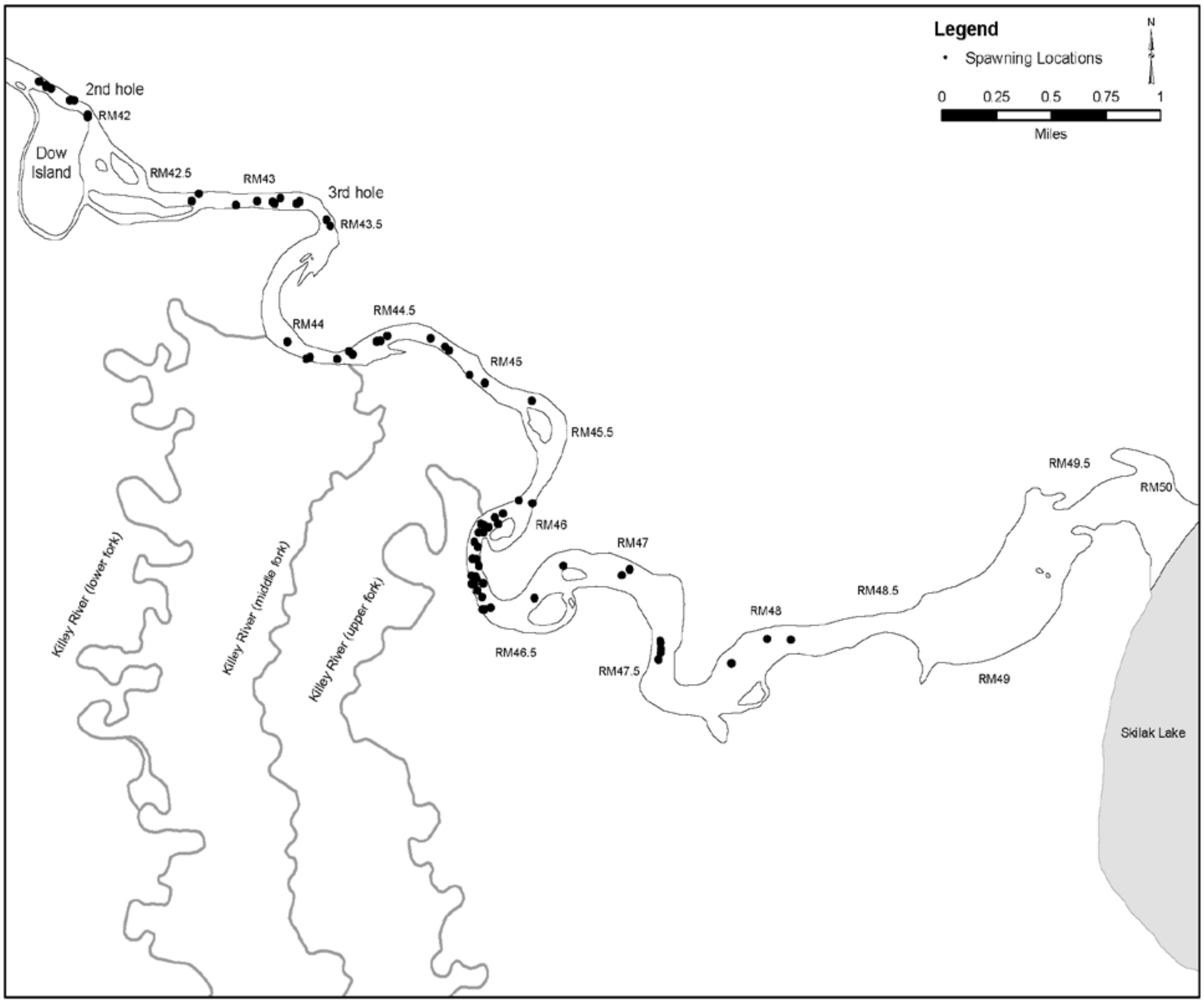
Appendix A2.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 22.3 and RM 28.3, 2010–2014.



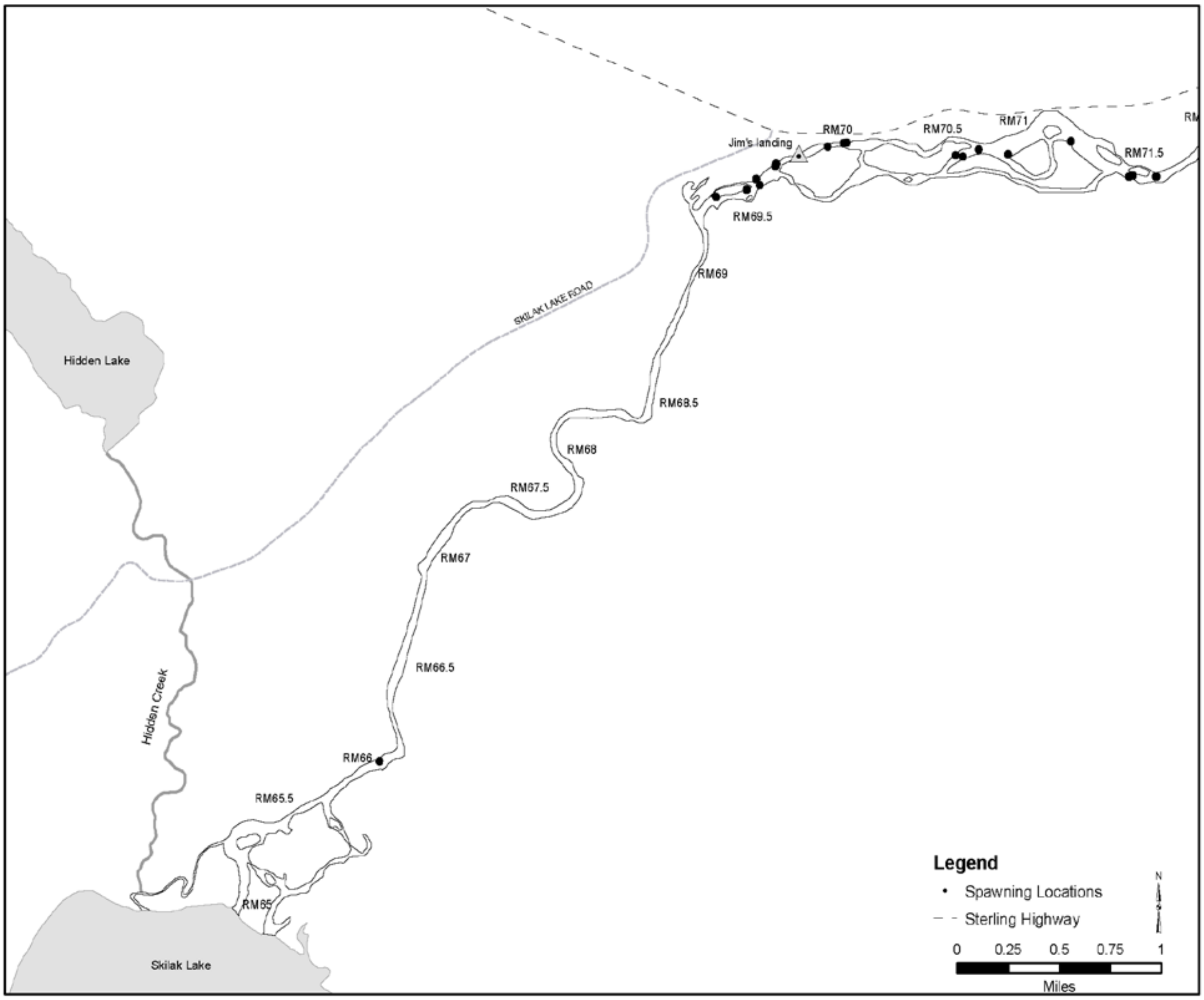
Appendix A3.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 28.3 and RM 34.2, 2010–2014.



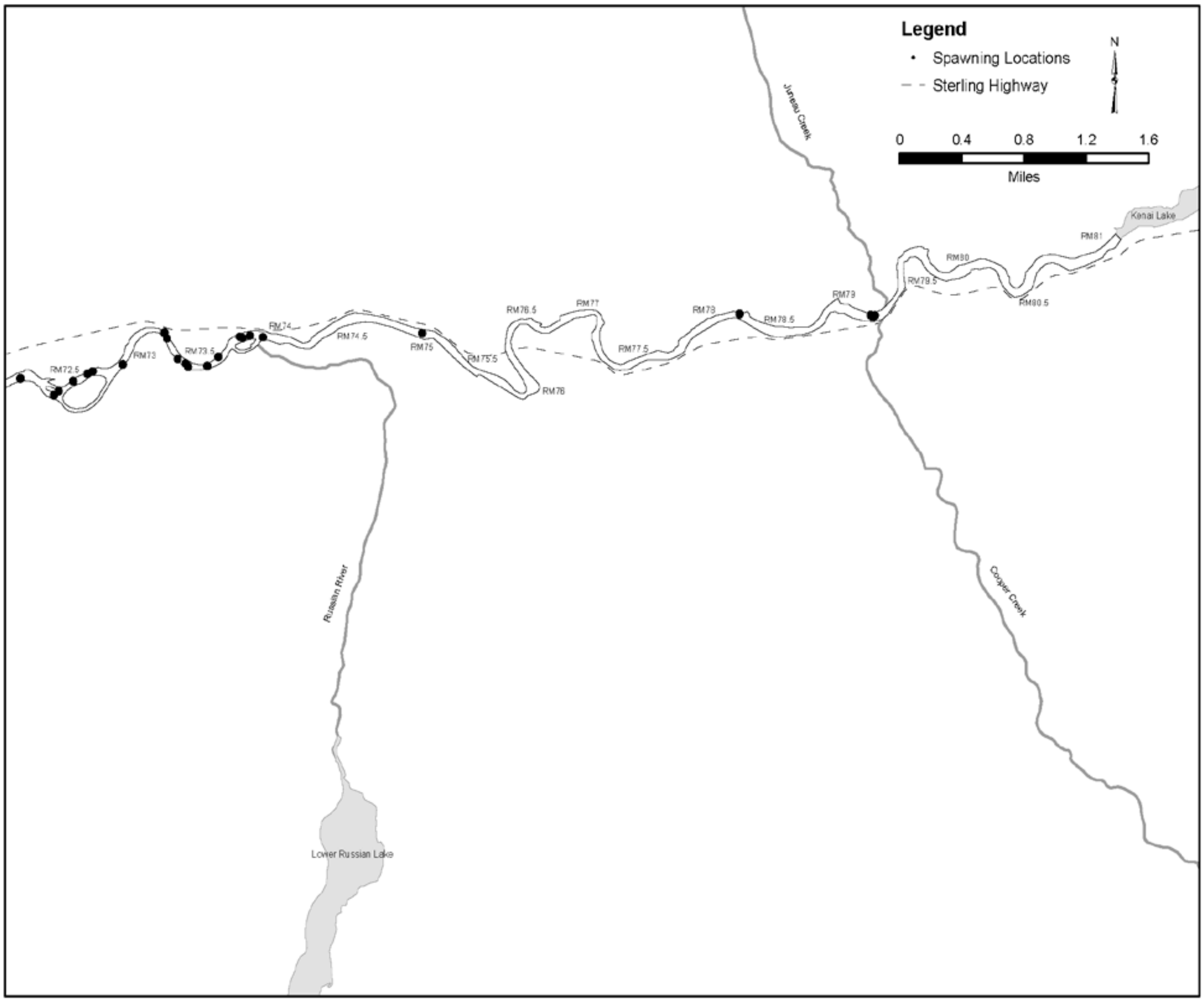
Appendix A4.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 34.2 and RM 41.6, 2010–2014.



Appendix A5.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 41.6 and Skilak Lake outlet (RM 50.0), 2010–2014.



Appendix A6.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between Skilak Lake Inlet (RM 65.0) and RM 72.0, 2010–2014.



Appendix A7.–Spawning destinations for radiotagged Kenai River Chinook salmon spawning between RM 72.0 and Kenai Lake outlet (RM 81.2), 2010–2014.

APPENDIX B: PROPORTION OF RADIOTAGGED KENAI RIVER CHINOOK SALMON DETECTED IN THE SPORT FISHERY UPSTREAM AND DOWNSTREAM OF SLIKOK CREEK BY ASSIGNED SPAWNING DESTINATION AND ENTRY TIMING, 2012–2014.

Appendix B1.–Proportions by assigned spawning destination and time of tagging (early or late run) of radiotagged Kenai River Chinook salmon detected in waters open to sport fishing upstream of Slikok Creek and the proportions downstream of Slikok Creek, 2012–2014.

		Detected downstream of Slikok Creek			Detected upstream of Slikok Creek		
		Tributary spawners	Mainstem spawners		Tributary spawners	Mainstem spawners	
			Early run [a]	Late run [b]		Early run [a]	Late run [b]
Year	Date	Prop. (SE)	Prop. (SE)	Prop. (SE)	Prop. (SE)	Prop. (SE)	Prop. (SE)
2012							
	1 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	6 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	11 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	16 Jun	0.5 (0.25)	0.5 (0.25)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	21 Jun	0.71 (0.17)	0.29 (0.17)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	26 Jun	0.71 (0.17)	0.29 (0.17)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	1 Jul	0.4 (0.22)	0.6 (0.22)	. (.)	0.78 (0.14)	0.22 (0.14)	. (.)
	6 Jul	0.09 (0.07)	0.18 (0.07)	0.73 (0.0)	0.55 (0.15)	0.45 (0.15)	0.0 (.)
	11 Jul	0.0 (0.0)	0.08 (0.0)	0.92 (0.0)	0.14 (0.12)	0.43 (0.12)	0.43 (0.0)
	16 Jul	0.0 (0.0)	0.05 (0.0)	0.95 (0.0)	0.09 (0.08)	0.45 (0.08)	0.45 (0.0)
	21 Jul	0.0 (0.0)	0.04 (0.0)	0.96 (0.0)	0.0 (0.0)	0.27 (0.0)	0.73 (0.0)
	26 Jul	0.0 (0.0)	0.03 (0.0)	0.97 (0.0)	0.0 (0.0)	0.13 (0.0)	0.87 (0.0)
	31 Jul	0.0 (0.0)	0.02 (0.0)	0.98 (0.0)	0.0 (0.0)	0.12 (0.0)	0.88 (0.0)
2013							
	1 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	6 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	11 Jun	0.82 (0.12)	0.18 (0.12)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	16 Jun	0.82 (0.12)	0.18 (0.12)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	21 Jun	0.6 (0.15)	0.4 (0.15)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	26 Jun	0.6 (0.15)	0.4 (0.15)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	1 Jul	0.0 (0.0)	1.0 (0.0)	. (.)	0.67 (0.19)	0.33 (0.19)	. (.)
	6 Jul	0.0 (0.0)	0.24 (0.0)	0.76 (0.0)	0.57 (0.19)	0.43 (0.19)	0.0 (.)
	11 Jul	0.0 (0.0)	0.08 (0.0)	0.92 (0.0)	0.27 (0.13)	0.35 (0.1)	0.38 (0.08)
	16 Jul	0.0 (0.0)	0.0 (.)	1.0 (0.0)	0.08 (0.07)	0.4 (0.07)	0.52 (0.0)
	21 Jul	0.0 (0.0)	0.0 (.)	1.0 (0.0)	0.09 (0.08)	0.4 (0.0)	0.52 (0.08)
	26 Jul	0.0 (0.0)	0.0 (.)	1.0 (0.0)	0.0 (0.0)	0.32 (0.0)	0.68 (0.0)
	31 Jul	0.0 (0.0)	0.0 (.)	1.0 (0.0)	0.0 (0.0)	0.29 (0.0)	0.71 (0.0)
2014							
	1 Jun	1.0 (0.0)	. (.)	. (.)	1.0 (0.0)	. (.)	. (.)
	6 Jun	0.92 (0.07)	0.08 (0.07)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	11 Jun	0.97 (0.03)	0.03 (0.03)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	16 Jun	0.88 (0.06)	0.12 (0.06)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	21 Jun	0.81 (0.09)	0.19 (0.09)	. (.)	1.0 (0.0)	0.0 (0.0)	. (.)
	26 Jun	0.5 (0.13)	0.5 (0.13)	. (.)	0.94 (0.04)	0.06 (0.04)	. (.)
	1 Jul	0.36 (0.15)	0.64 (0.15)	. (.)	0.83 (0.08)	0.17 (0.08)	. (.)
	6 Jul	0.0 (0.0)	0.34 (0.0)	0.66 (0.0)	0.48 (0.14)	0.25 (0.09)	0.27 (0.11)
	11 Jul	0.0 (0.0)	0.16 (0.0)	0.84 (0.0)	0.29 (0.16)	0.38 (0.08)	0.33 (0.14)
	16 Jul	0.0 (0.0)	0.06 (0.0)	0.94 (0.0)	0.18 (0.13)	0.15 (0.04)	0.67 (0.12)
	21 Jul	0.0 (0.0)	0.02 (0.0)	0.98 (0.0)	0.05 (0.04)	0.11 (0.04)	0.84 (0.0)
	26 Jul	0.0 (0.0)	0.03 (0.0)	0.97 (0.0)	0.03 (0.03)	0.07 (0.03)	0.9 (0.0)
	31 Jul	0.0 (0.0)	0.02 (0.0)	0.98 (0.0)	0.0 (0.0)	0.09 (0.0)	0.91 (0.0)

-continued-

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted protion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Note: Standard errors of zero occur when unweighted proportions in all 3 time strata equal either 0 or 1. Thus, their corresponding binomial variances, used to calculate total variance (Equation 5), equals zero. However, overall proportion calculated using the stratified estimator (Equation 4) can be nonzero because it represents the weighted proportion. Two factors contributed to this situation: 1) small sample sizes and 2) correlation of the tagging time strata with the entry timing.

[a] Fish captured and radiotagged during the early run.

[b] Fish captured and radiotagged during the late run.

APPENDIX C: PROPORTIONAL DISTRIBUTION BY GEOGRAPHIC AREA, MANAGEMENT AREA, AND DATE OF KENAI RIVER CHINOOK SALMON RADIOTAGGED AT RM 8.6, 2014.

Appendix C1.–Proportional distribution by date and area of Kenai River Chinook salmon radiotagged during the early run at RM 8.6, 2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (SE)	Prop. (SE)	Prop. (SE)
17 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
22 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
27 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1 Jun	0.71 (0.17)	0.29 (0.17)	0.0 (0.0)
6 Jun	0.67 (0.1)	0.14 (0.08)	0.19 (0.09)
11 Jun	0.62 (0.07)	0.19 (0.06)	0.19 (0.06)
16 Jun	0.46 (0.07)	0.29 (0.06)	0.25 (0.06)
21 Jun	0.33 (0.06)	0.39 (0.06)	0.28 (0.06)
26 Jun	0.21 (0.05)	0.47 (0.06)	0.31 (0.06)
1 Jul	0.14 (0.04)	0.3 (0.05)	0.56 (0.06)
6 Jul	0.05 (0.03)	0.16 (0.04)	0.79 (0.05)
11 Jul	0.04 (0.02)	0.11 (0.04)	0.85 (0.04)
16 Jul	0.01 (0.01)	0.06 (0.03)	0.93 (0.03)
21 Jul	0.02 (0.02)	0.05 (0.03)	0.94 (0.03)
26 Jul	0.04 (0.02)	0.05 (0.03)	0.91 (0.04)
31 Jul	0.02 (0.02)	0.06 (0.03)	0.92 (0.04)

Note: Results for 2010–2013 are presented in Reimer (2013).

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix C2.–Proportional distribution by year, date, and area of Kenai River Chinook salmon radiotagged during the late run at RM 8.6, 2012–2014.

		Downstream of Slikok Creek	Upstream of Slikok Creek	
			Unrestricted	Closed or restricted
Year	Date	Prop. (SE)	Prop. (SE)	Prop. (SE)
2012				
	1 Jul	1.0 (0.0)	. (.)	. (.)
	6 Jul	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	11 Jul	0.69 (0.69)	0.19 (0.09)	0.12 (0.11)
	16 Jul	0.75 (0.11)	0.18 (0.09)	0.07 (0.07)
	21 Jul	0.64 (0.1)	0.26 (0.09)	0.1 (0.06)
	26 Jul	0.59 (0.09)	0.34 (0.08)	0.07 (0.05)
	31 Jul	0.6 (0.07)	0.24 (0.06)	0.16 (0.05)
2013				
	1 Jul	1.0 (0.0)	0.0 (.)	. (.)
	6 Jul	0.86 (0.13)	0.0 (0.0)	0.14 (0.13)
	11 Jul	0.61 (0.11)	0.0 (0.11)	0.11 (0.07)
	16 Jul	0.71 (0.08)	0.0 (0.08)	0.07 (0.05)
	21 Jul	0.67 (0.07)	0.0 (0.06)	0.14 (0.06)
	26 Jul	0.68 (0.07)	0.0 (0.06)	0.11 (0.05)
	31 Jul	0.67 (0.05)	0.0 (0.05)	0.14 (0.05)
2014				
	1 Jul	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	6 Jul	0.5 (0.2)	0.5 (0.2)	0.0 (0.0)
	11 Jul	0.6 (0.15)	0.3 (0.14)	0.1 (0.09)
	16 Jul	0.5 (0.14)	0.5 (0.14)	0.0 (0.0)
	21 Jul	0.71 (0.09)	0.21 (0.08)	0.07 (0.05)
	26 Jul	0.62 (0.08)	0.29 (0.08)	0.09 (0.05)
	31 Jul	0.57 (0.08)	0.26 (0.07)	0.17 (0.06)

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix C3.–Proportional distribution by date and area of tributary-spawning Kenai River Chinook salmon radiotagged at RM 8.6, 2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (SE)	Prop. (SE)	Prop. (SE)
17 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
22 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
27 May	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1 Jun	0.71 (0.17)	0.29 (0.17)	0.0 (0.0)
6 Jun	0.65 (0.11)	0.15 (0.08)	0.2 (0.09)
11 Jun	0.61 (0.08)	0.2 (0.06)	0.2 (0.06)
16 Jun	0.45 (0.07)	0.29 (0.06)	0.25 (0.06)
21 Jun	0.29 (0.06)	0.42 (0.06)	0.29 (0.06)
26 Jun	0.15 (0.04)	0.5 (0.06)	0.35 (0.06)
1 Jul	0.06 (0.03)	0.3 (0.06)	0.64 (0.06)
6 Jul	0.0 (0.0)	0.14 (0.04)	0.86 (0.04)
11 Jul	0.0 (0.0)	0.08 (0.02)	0.92 (0.02)
16 Jul	0.0 (0.0)	0.06 (0.02)	0.94 (0.02)
21 Jul	0.0 (0.0)	0.02 (0.02)	0.98 (0.02)
26 Jul	0.0 (0.0)	0.02 (0.02)	0.98 (0.02)
31 Jul	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)

Note: Results for 2010–2013 are presented in Reimer (2013).

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix C4.–Proportional distribution by date and area of mainstem-spawning Kenai River Chinook salmon radiotagged at RM 8.6, 2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (SE)	Prop. (SE)	Prop. (SE)
16 Jun	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)
21 Jun	0.8 (0.18)	0.0 (0.0)	0.2 (0.18)
26 Jun	0.75 (0.15)	0.25 (0.15)	0.0 (0.0)
1 Jul	0.54 (0.14)	0.31 (0.13)	0.15 (0.1)
6 Jul	0.45 (0.13)	0.39 (0.13)	0.15 (0.06)
11 Jul	0.51 (0.11)	0.31 (0.1)	0.18 (0.08)
16 Jul	0.42 (0.11)	0.4 (0.11)	0.17 (0.04)
21 Jul	0.66 (0.07)	0.22 (0.07)	0.12 (0.04)
26 Jul	0.59 (0.08)	0.29 (0.07)	0.12 (0.04)
31 Jul	0.55 (0.07)	0.27 (0.07)	0.18 (0.05)

Note: Results for 2012–2013 are presented in Reimer (2013).

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

APPENDIX D: PROPORTIONAL DISTRIBUTION BY DATE AND AREA OF RADIOTAGGED KENAI RIVER CHINOOK SALMON, 2010–2014

Appendix D1.–Proportional distribution and 95% confidence intervals (CI) by date and area of Kenai River Chinook salmon radiotagged during the early run at RM 8.6 using a generalized additive model for 2012–2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
16 May	0.99 (0.92–1.00)	0.01 (0.00–0.08)	0.01 (0.00–0.04)
17 May	0.98 (0.92–1.00)	0.02 (0.00–0.08)	0.01 (0.00–0.04)
18 May	0.98 (0.92–0.99)	0.02 (0.00–0.08)	0.02 (0.01–0.05)
19 May	0.97 (0.91–0.99)	0.03 (0.01–0.09)	0.02 (0.01–0.05)
20 May	0.96 (0.91–0.99)	0.03 (0.01–0.09)	0.02 (0.01–0.05)
21 May	0.95 (0.90–0.98)	0.04 (0.02–0.10)	0.02 (0.01–0.05)
22 May	0.94 (0.89–0.97)	0.05 (0.03–0.10)	0.03 (0.01–0.05)
23 May	0.92 (0.87–0.96)	0.06 (0.04–0.11)	0.03 (0.02–0.06)
24 May	0.90 (0.85–0.94)	0.08 (0.05–0.13)	0.03 (0.02–0.06)
25 May	0.88 (0.83–0.92)	0.10 (0.06–0.15)	0.04 (0.02–0.07)
26 May	0.85 (0.80–0.89)	0.12 (0.08–0.17)	0.04 (0.03–0.07)
27 May	0.82 (0.76–0.86)	0.14 (0.10–0.19)	0.05 (0.03–0.08)
28 May	0.79 (0.73–0.83)	0.16 (0.12–0.21)	0.06 (0.04–0.08)
29 May	0.75 (0.70–0.80)	0.18 (0.14–0.22)	0.06 (0.05–0.09)
30 May	0.72 (0.67–0.77)	0.19 (0.16–0.24)	0.07 (0.05–0.09)
31 May	0.70 (0.65–0.74)	0.21 (0.17–0.25)	0.08 (0.06–0.10)
1 Jun	0.68 (0.63–0.72)	0.22 (0.18–0.26)	0.09 (0.07–0.11)
2 Jun	0.66 (0.62–0.70)	0.22 (0.19–0.27)	0.09 (0.07–0.12)
3 Jun	0.65 (0.61–0.69)	0.23 (0.19–0.27)	0.10 (0.08–0.12)
4 Jun	0.65 (0.61–0.69)	0.23 (0.19–0.26)	0.11 (0.09–0.13)
5 Jun	0.65 (0.61–0.68)	0.22 (0.19–0.26)	0.12 (0.10–0.14)
6 Jun	0.65 (0.61–0.68)	0.22 (0.19–0.25)	0.13 (0.11–0.15)
7 Jun	0.65 (0.61–0.68)	0.21 (0.19–0.24)	0.14 (0.12–0.16)
8 Jun	0.65 (0.62–0.68)	0.21 (0.18–0.23)	0.15 (0.13–0.17)
9 Jun	0.64 (0.61–0.67)	0.20 (0.18–0.23)	0.16 (0.14–0.18)
10 Jun	0.64 (0.61–0.67)	0.20 (0.18–0.22)	0.17 (0.15–0.19)
11 Jun	0.63 (0.60–0.65)	0.20 (0.18–0.22)	0.18 (0.16–0.20)
12 Jun	0.61 (0.58–0.64)	0.20 (0.18–0.22)	0.19 (0.18–0.21)
13 Jun	0.59 (0.56–0.62)	0.21 (0.19–0.23)	0.21 (0.19–0.23)
14 Jun	0.57 (0.54–0.59)	0.21 (0.19–0.24)	0.22 (0.20–0.24)
15 Jun	0.54 (0.51–0.56)	0.22 (0.20–0.25)	0.24 (0.22–0.26)
16 Jun	0.51 (0.48–0.53)	0.24 (0.22–0.26)	0.25 (0.23–0.27)
17 Jun	0.48 (0.45–0.50)	0.25 (0.23–0.27)	0.27 (0.25–0.29)
18 Jun	0.44 (0.42–0.47)	0.27 (0.25–0.29)	0.28 (0.26–0.30)
19 Jun	0.41 (0.39–0.43)	0.28 (0.26–0.30)	0.30 (0.28–0.32)
20 Jun	0.38 (0.36–0.40)	0.30 (0.27–0.32)	0.32 (0.30–0.34)
21 Jun	0.35 (0.33–0.38)	0.31 (0.29–0.33)	0.34 (0.32–0.36)
22 Jun	0.33 (0.31–0.35)	0.32 (0.30–0.34)	0.36 (0.34–0.38)
23 Jun	0.30 (0.28–0.33)	0.32 (0.30–0.34)	0.38 (0.36–0.40)
24 Jun	0.28 (0.27–0.31)	0.32 (0.30–0.34)	0.40 (0.38–0.42)
25 Jun	0.27 (0.25–0.29)	0.32 (0.30–0.34)	0.42 (0.40–0.44)
26 Jun	0.25 (0.23–0.27)	0.31 (0.29–0.33)	0.45 (0.43–0.47)

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Date	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
27 Jun	0.23 (0.22–0.25)	0.30 (0.28–0.32)	0.47 (0.45–0.49)
28 Jun	0.22 (0.20–0.24)	0.28 (0.26–0.30)	0.50 (0.48–0.52)
29 Jun	0.21 (0.19–0.22)	0.27 (0.25–0.29)	0.53 (0.51–0.55)
30 Jun	0.19 (0.18–0.21)	0.25 (0.23–0.27)	0.56 (0.54–0.58)
1 Jul	0.18 (0.16–0.19)	0.23 (0.21–0.25)	0.59 (0.57–0.61)
2 Jul	0.16 (0.15–0.18)	0.21 (0.20–0.23)	0.62 (0.60–0.64)
3 Jul	0.15 (0.14–0.17)	0.19 (0.18–0.21)	0.65 (0.63–0.67)
4 Jul	0.14 (0.13–0.15)	0.18 (0.16–0.19)	0.68 (0.66–0.69)
5 Jul	0.13 (0.12–0.14)	0.16 (0.15–0.18)	0.70 (0.69–0.72)
6 Jul	0.12 (0.11–0.13)	0.15 (0.14–0.17)	0.72 (0.71–0.74)
7 Jul	0.11 (0.10–0.12)	0.14 (0.13–0.16)	0.74 (0.73–0.76)
8 Jul	0.10 (0.09–0.11)	0.13 (0.12–0.15)	0.76 (0.75–0.78)
9 Jul	0.09 (0.08–0.10)	0.13 (0.12–0.14)	0.78 (0.76–0.79)
10 Jul	0.09 (0.08–0.10)	0.12 (0.11–0.13)	0.79 (0.78–0.80)
11 Jul	0.08 (0.07–0.09)	0.12 (0.11–0.13)	0.80 (0.79–0.81)
12 Jul	0.07 (0.07–0.09)	0.12 (0.10–0.13)	0.81 (0.80–0.82)
13 Jul	0.07 (0.06–0.08)	0.11 (0.10–0.13)	0.82 (0.80–0.83)
14 Jul	0.07 (0.06–0.07)	0.11 (0.10–0.13)	0.82 (0.81–0.83)
15 Jul	0.06 (0.05–0.07)	0.11 (0.10–0.13)	0.83 (0.81–0.84)
16 Jul	0.06 (0.05–0.07)	0.11 (0.10–0.13)	0.83 (0.82–0.84)
17 Jul	0.05 (0.05–0.06)	0.11 (0.10–0.13)	0.83 (0.82–0.85)
18 Jul	0.05 (0.04–0.06)	0.12 (0.10–0.13)	0.84 (0.82–0.85)
19 Jul	0.05 (0.04–0.05)	0.12 (0.11–0.13)	0.84 (0.83–0.85)
20 Jul	0.04 (0.04–0.05)	0.12 (0.11–0.13)	0.84 (0.83–0.85)
21 Jul	0.04 (0.03–0.05)	0.12 (0.11–0.13)	0.84 (0.83–0.85)
22 Jul	0.04 (0.03–0.05)	0.12 (0.11–0.13)	0.84 (0.83–0.85)
23 Jul	0.04 (0.03–0.04)	0.12 (0.11–0.14)	0.84 (0.83–0.85)
24 Jul	0.04 (0.03–0.04)	0.12 (0.11–0.14)	0.84 (0.83–0.85)
25 Jul	0.03 (0.03–0.04)	0.12 (0.11–0.14)	0.84 (0.83–0.85)
26 Jul	0.03 (0.03–0.04)	0.13 (0.11–0.14)	0.84 (0.83–0.85)
27 Jul	0.03 (0.03–0.04)	0.13 (0.11–0.14)	0.84 (0.83–0.85)
28 Jul	0.03 (0.03–0.04)	0.13 (0.11–0.14)	0.84 (0.82–0.85)
29 Jul	0.03 (0.03–0.04)	0.13 (0.11–0.14)	0.84 (0.82–0.85)
30 Jul	0.03 (0.02–0.04)	0.13 (0.11–0.15)	0.84 (0.82–0.86)
31 Jul	0.03 (0.02–0.05)	0.13 (0.11–0.15)	0.84 (0.81–0.86)

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix D2.–Proportional distribution and 95% confidence intervals (CI) by date and area of Kenai River Chinook salmon radiotagged during the late run at RM 8.6 using a generalized additive model for 2012–2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
1 Jul	0.91 (0.75–0.97)	0.02 (0.01–0.08)	0.01 (0.00–0.08)
2 Jul	0.89 (0.75–0.96)	0.03 (0.01–0.09)	0.02 (0.00–0.07)
3 Jul	0.86 (0.75–0.93)	0.04 (0.02–0.10)	0.02 (0.01–0.08)
4 Jul	0.84 (0.73–0.90)	0.06 (0.03–0.11)	0.03 (0.01–0.08)
5 Jul	0.80 (0.71–0.87)	0.08 (0.05–0.13)	0.05 (0.02–0.09)
6 Jul	0.77 (0.69–0.83)	0.11 (0.07–0.15)	0.06 (0.04–0.10)
7 Jul	0.74 (0.66–0.80)	0.13 (0.10–0.18)	0.08 (0.05–0.12)
8 Jul	0.71 (0.64–0.77)	0.16 (0.12–0.21)	0.09 (0.06–0.14)
9 Jul	0.69 (0.62–0.75)	0.19 (0.15–0.24)	0.10 (0.07–0.15)
10 Jul	0.67 (0.60–0.73)	0.22 (0.17–0.27)	0.11 (0.08–0.16)
11 Jul	0.66 (0.60–0.72)	0.23 (0.19–0.28)	0.12 (0.08–0.16)
12 Jul	0.66 (0.60–0.71)	0.24 (0.20–0.29)	0.12 (0.09–0.16)
13 Jul	0.66 (0.60–0.71)	0.25 (0.21–0.30)	0.11 (0.08–0.15)
14 Jul	0.67 (0.61–0.72)	0.25 (0.21–0.30)	0.11 (0.08–0.15)
15 Jul	0.68 (0.62–0.73)	0.25 (0.21–0.29)	0.10 (0.08–0.14)
16 Jul	0.68 (0.63–0.73)	0.25 (0.21–0.29)	0.10 (0.07–0.13)
17 Jul	0.69 (0.64–0.73)	0.24 (0.20–0.28)	0.10 (0.07–0.13)
18 Jul	0.68 (0.64–0.73)	0.24 (0.20–0.28)	0.10 (0.07–0.13)
19 Jul	0.68 (0.63–0.72)	0.24 (0.20–0.28)	0.10 (0.08–0.13)
20 Jul	0.66 (0.62–0.71)	0.24 (0.21–0.28)	0.11 (0.09–0.14)
21 Jul	0.65 (0.60–0.69)	0.25 (0.21–0.29)	0.12 (0.09–0.15)
22 Jul	0.64 (0.59–0.68)	0.26 (0.22–0.30)	0.13 (0.10–0.16)
23 Jul	0.63 (0.58–0.67)	0.27 (0.23–0.31)	0.13 (0.10–0.16)
24 Jul	0.62 (0.57–0.66)	0.28 (0.25–0.32)	0.13 (0.10–0.16)
25 Jul	0.62 (0.57–0.66)	0.29 (0.25–0.33)	0.13 (0.10–0.16)
26 Jul	0.62 (0.57–0.66)	0.30 (0.26–0.34)	0.13 (0.10–0.16)
27 Jul	0.62 (0.57–0.66)	0.30 (0.26–0.34)	0.13 (0.10–0.16)
28 Jul	0.62 (0.58–0.66)	0.29 (0.26–0.33)	0.13 (0.10–0.16)
29 Jul	0.62 (0.57–0.67)	0.29 (0.25–0.32)	0.14 (0.11–0.17)
30 Jul	0.62 (0.55–0.68)	0.28 (0.24–0.32)	0.15 (0.12–0.18)
31 Jul	0.57 (0.50–0.63)	0.27 (0.21–0.33)	0.16 (0.12–0.22)

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix D3.–Proportional distribution by date and area and 95% confidence intervals (CI) of tributary-spawning Kenai River Chinook salmon radiotagged at RM 8.6 using a generalized additive model for 2010–2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
16 May	0.99 (0.93–1.00)	0.01 (0.00–0.08)	0.00 (0.00–0.05)
17 May	0.99 (0.92–1.00)	0.02 (0.00–0.08)	0.01 (0.00–0.05)
18 May	0.98 (0.92–1.00)	0.02 (0.01–0.08)	0.01 (0.00–0.04)
19 May	0.98 (0.92–0.99)	0.03 (0.01–0.09)	0.01 (0.00–0.04)
20 May	0.97 (0.91–0.99)	0.04 (0.01–0.09)	0.01 (0.00–0.04)
21 May	0.96 (0.90–0.98)	0.04 (0.02–0.10)	0.01 (0.00–0.05)
22 May	0.94 (0.89–0.97)	0.06 (0.03–0.11)	0.02 (0.01–0.05)
23 May	0.93 (0.87–0.96)	0.07 (0.04–0.12)	0.02 (0.01–0.05)
24 May	0.91 (0.85–0.94)	0.08 (0.05–0.13)	0.02 (0.01–0.06)
25 May	0.88 (0.83–0.92)	0.10 (0.07–0.15)	0.03 (0.02–0.06)
26 May	0.85 (0.79–0.89)	0.12 (0.08–0.17)	0.04 (0.02–0.07)
27 May	0.82 (0.76–0.86)	0.14 (0.10–0.19)	0.05 (0.03–0.08)
28 May	0.78 (0.73–0.83)	0.16 (0.12–0.20)	0.05 (0.03–0.09)
29 May	0.75 (0.70–0.80)	0.17 (0.14–0.22)	0.06 (0.04–0.09)
30 May	0.72 (0.67–0.77)	0.19 (0.15–0.23)	0.07 (0.05–0.10)
31 May	0.69 (0.65–0.74)	0.20 (0.17–0.25)	0.08 (0.06–0.11)
1 Jun	0.67 (0.63–0.72)	0.21 (0.18–0.26)	0.09 (0.07–0.12)
2 Jun	0.66 (0.61–0.70)	0.22 (0.19–0.26)	0.10 (0.08–0.13)
3 Jun	0.65 (0.61–0.69)	0.22 (0.19–0.26)	0.11 (0.09–0.14)
4 Jun	0.65 (0.60–0.68)	0.23 (0.19–0.26)	0.12 (0.10–0.15)
5 Jun	0.64 (0.60–0.68)	0.22 (0.19–0.26)	0.13 (0.11–0.16)
6 Jun	0.64 (0.61–0.68)	0.22 (0.19–0.25)	0.14 (0.11–0.16)
7 Jun	0.64 (0.61–0.68)	0.22 (0.19–0.25)	0.14 (0.12–0.17)
8 Jun	0.64 (0.61–0.67)	0.21 (0.19–0.24)	0.15 (0.13–0.17)
9 Jun	0.64 (0.61–0.67)	0.21 (0.19–0.24)	0.16 (0.14–0.18)
10 Jun	0.63 (0.60–0.66)	0.21 (0.18–0.23)	0.17 (0.15–0.19)
11 Jun	0.62 (0.59–0.65)	0.21 (0.19–0.23)	0.18 (0.16–0.21)
12 Jun	0.60 (0.57–0.63)	0.21 (0.19–0.23)	0.19 (0.17–0.22)
13 Jun	0.58 (0.55–0.61)	0.22 (0.19–0.24)	0.21 (0.19–0.23)
14 Jun	0.55 (0.52–0.58)	0.22 (0.20–0.25)	0.23 (0.20–0.25)
15 Jun	0.52 (0.49–0.55)	0.23 (0.21–0.26)	0.24 (0.22–0.27)
16 Jun	0.48 (0.46–0.51)	0.25 (0.23–0.27)	0.26 (0.24–0.29)
17 Jun	0.45 (0.42–0.48)	0.26 (0.24–0.29)	0.28 (0.26–0.31)
18 Jun	0.41 (0.38–0.44)	0.28 (0.26–0.30)	0.30 (0.28–0.33)
19 Jun	0.37 (0.35–0.40)	0.30 (0.28–0.32)	0.32 (0.30–0.35)
20 Jun	0.34 (0.31–0.36)	0.32 (0.29–0.34)	0.34 (0.32–0.37)
21 Jun	0.31 (0.28–0.33)	0.33 (0.31–0.35)	0.36 (0.34–0.39)
22 Jun	0.27 (0.25–0.30)	0.34 (0.32–0.37)	0.38 (0.36–0.41)
23 Jun	0.25 (0.23–0.27)	0.35 (0.33–0.37)	0.41 (0.38–0.43)
24 Jun	0.22 (0.20–0.24)	0.35 (0.33–0.38)	0.43 (0.41–0.45)
25 Jun	0.20 (0.18–0.22)	0.35 (0.33–0.37)	0.46 (0.43–0.48)
26 Jun	0.17 (0.15–0.19)	0.34 (0.32–0.36)	0.49 (0.46–0.51)

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	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
27 Jun	0.15 (0.13–0.17)	0.33 (0.30–0.35)	0.52 (0.50–0.55)
28 Jun	0.13 (0.12–0.15)	0.31 (0.28–0.33)	0.56 (0.54–0.59)
29 Jun	0.11 (0.10–0.13)	0.28 (0.26–0.30)	0.60 (0.58–0.63)
1 Jul	0.08 (0.07–0.09)	0.23 (0.21–0.25)	0.69 (0.67–0.71)
2 Jul	0.07 (0.06–0.08)	0.20 (0.19–0.22)	0.73 (0.71–0.75)
3 Jul	0.06 (0.05–0.07)	0.18 (0.16–0.20)	0.77 (0.74–0.78)
4 Jul	0.05 (0.04–0.06)	0.16 (0.14–0.17)	0.80 (0.78–0.82)
5 Jul	0.04 (0.03–0.05)	0.14 (0.12–0.15)	0.83 (0.81–0.84)
6 Jul	0.03 (0.02–0.04)	0.12 (0.11–0.14)	0.85 (0.84–0.87)
7 Jul	0.02 (0.02–0.03)	0.11 (0.09–0.12)	0.87 (0.86–0.89)
8 Jul	0.02 (0.01–0.03)	0.09 (0.08–0.11)	0.89 (0.87–0.90)
9 Jul	0.02 (0.01–0.02)	0.08 (0.07–0.10)	0.90 (0.89–0.91)
10 Jul	0.01 (0.01–0.02)	0.08 (0.07–0.09)	0.91 (0.90–0.92)
11 Jul	0.01 (0.01–0.01)	0.07 (0.06–0.08)	0.92 (0.91–0.93)
12 Jul	0.01 (0.00–0.01)	0.06 (0.05–0.07)	0.93 (0.92–0.94)
13 Jul	0.01 (0.00–0.01)	0.06 (0.05–0.07)	0.94 (0.93–0.95)
14 Jul	0.00 (0.00–0.01)	0.05 (0.04–0.06)	0.94 (0.93–0.95)
15 Jul	0.00 (0.00–0.01)	0.05 (0.04–0.06)	0.95 (0.94–0.96)
16 Jul	0.00 (0.00–0.00)	0.04 (0.04–0.05)	0.95 (0.94–0.96)
17 Jul	0.00 (0.00–0.00)	0.04 (0.03–0.05)	0.96 (0.95–0.97)
18 Jul	0.00 (0.00–0.00)	0.04 (0.03–0.05)	0.96 (0.95–0.97)
19 Jul	0.00 (0.00–0.00)	0.03 (0.03–0.04)	0.97 (0.96–0.97)
20 Jul	0.00 (0.00–0.00)	0.03 (0.02–0.04)	0.97 (0.96–0.98)
21 Jul	0.00 (0.00–0.00)	0.03 (0.02–0.04)	0.97 (0.96–0.98)
22 Jul	0.00 (0.00–0.00)	0.03 (0.02–0.03)	0.97 (0.97–0.98)
23 Jul	0.00 (0.00–0.00)	0.02 (0.02–0.03)	0.98 (0.97–0.98)
24 Jul	0.00 (0.00–0.00)	0.02 (0.02–0.03)	0.98 (0.97–0.98)
25 Jul	0.00 (0.00–0.00)	0.02 (0.01–0.03)	0.98 (0.97–0.99)
26 Jul	0.00 (0.00–0.00)	0.02 (0.01–0.03)	0.98 (0.97–0.99)
27 Jul	0.00 (0.00–0.00)	0.02 (0.01–0.03)	0.98 (0.98–0.99)
28 Jul	0.00 (0.00–0.00)	0.02 (0.01–0.03)	0.98 (0.98–0.99)
29 Jul	0.00 (0.00–0.00)	0.02 (0.01–0.03)	0.98 (0.97–0.99)
30 Jul	0.00 (0.00–0.00)	0.01 (0.01–0.03)	0.99 (0.97–0.99)
31 Jul	0.00 (0.00–0.00)	0.01 (0.01–0.03)	0.99 (0.97–0.99)

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.

Appendix D4.–Proportional distribution and 95% confidence intervals (CI) by date and area of mainstem-spawning Kenai River Chinook salmon radiotagged at RM 8.6 using a generalized additive model for 2012–2014.

	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
9 Jun	1.00 (0.95–1.00)	0.00 (0.00–0.05)	0.01 (0.00–0.08)
10 Jun	0.99 (0.95–1.00)	0.00 (0.00–0.05)	0.01 (0.00–0.08)
11 Jun	0.99 (0.95–1.00)	0.00 (0.00–0.05)	0.01 (0.00–0.08)
12 Jun	0.99 (0.94–1.00)	0.00 (0.00–0.05)	0.02 (0.00–0.08)
13 Jun	0.99 (0.94–1.00)	0.00 (0.00–0.05)	0.02 (0.00–0.08)
14 Jun	0.98 (0.93–1.00)	0.01 (0.00–0.05)	0.02 (0.01–0.08)
15 Jun	0.98 (0.92–0.99)	0.01 (0.00–0.05)	0.03 (0.01–0.09)
16 Jun	0.97 (0.91–0.99)	0.01 (0.00–0.05)	0.03 (0.01–0.09)
17 Jun	0.96 (0.90–0.99)	0.01 (0.00–0.06)	0.04 (0.01–0.09)
18 Jun	0.95 (0.89–0.98)	0.02 (0.00–0.07)	0.04 (0.02–0.10)
19 Jun	0.94 (0.87–0.97)	0.02 (0.01–0.07)	0.05 (0.02–0.11)
20 Jun	0.92 (0.85–0.96)	0.03 (0.01–0.08)	0.06 (0.03–0.11)
21 Jun	0.90 (0.83–0.94)	0.04 (0.02–0.09)	0.07 (0.04–0.12)
22 Jun	0.87 (0.80–0.92)	0.05 (0.03–0.11)	0.08 (0.05–0.13)
23 Jun	0.84 (0.77–0.90)	0.07 (0.04–0.13)	0.09 (0.05–0.14)
24 Jun	0.81 (0.74–0.87)	0.09 (0.05–0.14)	0.10 (0.06–0.15)
25 Jun	0.78 (0.71–0.84)	0.11 (0.07–0.17)	0.11 (0.08–0.16)
26 Jun	0.74 (0.67–0.80)	0.13 (0.08–0.19)	0.13 (0.09–0.18)
27 Jun	0.71 (0.64–0.77)	0.15 (0.10–0.21)	0.14 (0.10–0.19)
28 Jun	0.67 (0.60–0.73)	0.17 (0.13–0.23)	0.15 (0.11–0.20)
29 Jun	0.64 (0.57–0.70)	0.19 (0.15–0.25)	0.16 (0.12–0.21)
30 Jun	0.60 (0.54–0.67)	0.21 (0.16–0.27)	0.18 (0.14–0.23)
1 Jul	0.58 (0.52–0.64)	0.23 (0.18–0.29)	0.19 (0.15–0.23)
2 Jul	0.56 (0.50–0.61)	0.25 (0.20–0.30)	0.19 (0.15–0.24)
3 Jul	0.54 (0.48–0.59)	0.26 (0.21–0.31)	0.20 (0.16–0.25)
4 Jul	0.53 (0.47–0.58)	0.27 (0.22–0.32)	0.20 (0.16–0.25)
5 Jul	0.52 (0.47–0.57)	0.28 (0.23–0.33)	0.20 (0.17–0.25)
6 Jul	0.51 (0.46–0.56)	0.29 (0.24–0.34)	0.20 (0.17–0.24)
7 Jul	0.51 (0.46–0.56)	0.30 (0.25–0.35)	0.20 (0.16–0.24)
8 Jul	0.51 (0.46–0.56)	0.30 (0.26–0.35)	0.19 (0.16–0.23)
9 Jul	0.51 (0.47–0.56)	0.31 (0.27–0.36)	0.19 (0.16–0.22)
10 Jul	0.52 (0.47–0.56)	0.31 (0.27–0.36)	0.18 (0.15–0.22)
11 Jul	0.52 (0.48–0.57)	0.31 (0.27–0.36)	0.18 (0.15–0.21)
12 Jul	0.53 (0.49–0.57)	0.31 (0.27–0.35)	0.17 (0.14–0.20)
13 Jul	0.54 (0.50–0.58)	0.31 (0.27–0.35)	0.16 (0.14–0.19)
14 Jul	0.55 (0.51–0.59)	0.30 (0.26–0.34)	0.16 (0.13–0.19)
15 Jul	0.56 (0.52–0.60)	0.30 (0.26–0.34)	0.15 (0.13–0.18)
16 Jul	0.57 (0.53–0.61)	0.29 (0.26–0.33)	0.15 (0.12–0.17)
17 Jul	0.58 (0.54–0.62)	0.29 (0.25–0.32)	0.14 (0.12–0.17)
18 Jul	0.59 (0.55–0.62)	0.28 (0.25–0.32)	0.13 (0.11–0.16)
19 Jul	0.59 (0.55–0.63)	0.28 (0.25–0.32)	0.13 (0.11–0.15)
20 Jul	0.59 (0.56–0.63)	0.28 (0.25–0.32)	0.13 (0.11–0.15)

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	Downstream of Slikok Creek	Upstream of Slikok Creek	
		Unrestricted	Closed or restricted
Date	Prop. (5–95% CI)	Prop. (5–95% CI)	Prop. (5–95% CI)
21 Jul	0.59 (0.56–0.63)	0.28 (0.25–0.32)	0.12 (0.10–0.15)
22 Jul	0.59 (0.55–0.62)	0.29 (0.26–0.32)	0.12 (0.10–0.15)
23 Jul	0.59 (0.55–0.62)	0.29 (0.26–0.33)	0.12 (0.10–0.15)
24 Jul	0.58 (0.55–0.62)	0.30 (0.26–0.33)	0.12 (0.10–0.15)
25 Jul	0.58 (0.54–0.61)	0.30 (0.26–0.33)	0.13 (0.11–0.15)
26 Jul	0.57 (0.54–0.61)	0.30 (0.26–0.33)	0.13 (0.11–0.15)
27 Jul	0.57 (0.54–0.61)	0.29 (0.26–0.33)	0.13 (0.11–0.15)
28 Jul	0.57 (0.54–0.60)	0.29 (0.26–0.32)	0.13 (0.11–0.16)
29 Jul	0.57 (0.54–0.61)	0.28 (0.25–0.31)	0.14 (0.12–0.16)
30 Jul	0.58 (0.53–0.62)	0.27 (0.24–0.31)	0.14 (0.12–0.18)
31 Jul	0.58 (0.52–0.63)	0.26 (0.22–0.32)	0.15 (0.11–0.19)

Note: "Downstream of Slikok Creek" includes Cook Inlet to Slikok Creek (RM 0–19). The unrestricted portion of "Upstream of Slikok Creek" includes Slikok Creek to Skilak Lake (RM 19–50) excluding closed or restricted fishing areas around Slikok Creek, Centennial Park, Funny River, Morgan's Landing, and Killey River. Closed or restricted waters describe the exclusions noted above plus the Kenai River upstream of and including Skilak Lake and all tributaries to the Kenai River drainage.