Fishery Data Series No. 17-35

Abundance, Distribution, and Migration Patterns of Summer Chum Salmon in the Yukon River Drainage, 2014-2015

by

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

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

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

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. 17-35

ABUNDANCE, DISTRIBUTION, AND MIGRATION PATTERNS OF SUMMER CHUM SALMON IN THE YUKON RIVER DRAINAGE, 2014-2015

by
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ABSTRACT

Summer chum salmon (*Oncorhynchus keta*) in the Yukon River support robust commercial and subsistence fisheries; however, fishery managers have had incomplete information about their run timing, spawning distribution, stock composition, and abundance. To address this, a radiotelemetry study was implemented on summer chum salmon in 2014 and 2015. A total of 1,232 (2014) and 1,199 (2015) summer chum salmon were fitted with radio transmitters. Radiotagged summer chum salmon were mapped, travel rates were estimated, and proportions of tagged fish recovered within different tributaries were determined. Basic mark–recapture assumptions were tested and abundance above the tagging site was estimated. Summer chum salmon were found to be widely distributed within the Yukon River drainage. Although a few tagged fish were observed in most locations, roughly 50% of tagged fish were observed in the Anvik, Koyukuk, and Bonasila rivers each year. Summer chum salmon destined for upper river spawning areas traveled faster than those to lower river areas. Summer chum salmon tended to recover quickly after being tagged, and traveled relatively fast within the mainstem Yukon River, but slowed down after entering their spawning tributaries. The 2014 mark–recapture abundance estimate was about 2,100,000 fish, which corresponded with summer chum salmon passage at the mainstem Yukon River sonar near Pilot Station. The 2015 mark–recapture abundance estimate was also about 2,100,000 fish, which was larger than the summer chum salmon passage at the sonar near Pilot Station. Results from this study help to evaluate sonar passage estimates and provide fishery managers with more detailed information about distribution and migratory patterns of individual summer chum salmon stocks within the Yukon River drainagewide population.

Key words: chum salmon, *Oncorhynchus keta*, radio tag, radiotelemetry, mark–recapture, Yukon River

INTRODUCTION

Subsistence fisheries in the Yukon River drainage are among the largest in Alaska. The importance of summer chum salmon (*Oncorhynchus keta*) to these fisheries has increased substantially in the last 20 years largely due to strict conservation measures on Chinook salmon (*O. tshawytscha*) fishing. Directed commercial fishing on Chinook salmon has not occurred since 2007 and there have been unprecedented restrictions on subsistence fishing for Chinook salmon since 2011. Subsistence Chinook salmon harvests have annually fallen below the amount necessary for subsistence (45,500 fish) since 2007 (Jallen et al. 2015; JTC 2015). Subsistence and commercial fishermen have increasingly targeted summer chum salmon to supplement or replace Chinook salmon harvest. In 2014, the total harvest of summer chum salmon in the Yukon River was the highest observed since 1996, whereas the total harvest of Chinook salmon was the lowest on record (JTC 2015). A productive summer chum salmon commercial fishery provides a much needed economic opportunity to one of the poorest areas of Alaska and market conditions for this species have improved recently. Revenue from commercial fishing helps pay for the supplies necessary to subsistence fish and hunt, including gas and fishing gear (Jallen et al. 2015). Understanding the dynamics of the Yukon River summer chum salmon stock group is crucial for long-term, sustainable, and well informed management because fishing efforts are expected to continue to focus on summer chum salmon.

Summer chum salmon returns to the Yukon River drainage in recent years have generally been strong. On average, about 1.6 million summer chum salmon migrated past the mainstem Yukon River sonar project near Pilot station (hereafter referred to as Pilot Station sonar) through the 1997–2013 period. However, this period also included some of the smallest runs, which occurred during a widespread chum salmon crisis period in Western Alaska. Summer chum salmon passage at the Pilot Station sonar dropped below 500,000 in 2000 and 2001, but then quickly rebounded to former levels. Summer chum salmon returns remained strong through the 2002–2013 period (Estensen et al. 2015a).

An understanding of relative stock contribution, run timing, and travel rates is needed to identify how management actions affect salmon stocks; however, this information is largely unknown for summer chum salmon. Summer chum escapement is monitored on the Andreafsky, Anvik, Gisasa, Chena, and Salcha rivers, and on Henshaw Creek using sonar, weir, or counting towers (JTC 2015). Even with these assessment projects, we lack adequate escapement estimates for summer chum salmon in numerous tributaries of the Yukon River and the distribution of stocks among spawning areas is poorly understood. Increased effort using aerial surveys has not produced sufficient and reliable information to address these data gaps, largely because the immense size of the Yukon River drainage and its extensive network of tributaries. Weirs and counting towers are expensive to operate and require prioritization among numerous potential sites, many of which are subject to unfavorable river conditions. The existing chum salmon genetic baseline defines broad lower, upper, and Tanana River stock groupings, but does not provide for discrimination among various lower Yukon River chum salmon stocks in mixed stock analysis (Flannery et al. 2010; Flannery and Wenburg 2014).

A firm understanding of salmon spawning habitat is important and habitat areas warranting protection should be identified while most of the area is still undeveloped. Given the immense size of the Yukon River drainage, it is likely that there are spawning areas for summer chum salmon that have yet to be identified. Protection of habitat used by anadromous fishes is provided to specified water bodies listed in the anadromous waters catalog (AWC), and therefore an important objective of this project is to identify key habitat areas to include in the AWC (Johnson and Daigneault 2013a and 2013b).

Summer chum salmon management has relied heavily on the Pilot Station sonar assessment in the lower mainstem river and a tributary sonar assessment located on the Anvik River (hereafter referred to the Anvik River sonar). The Pilot Station sonar (rkm 198) provides passage estimates of the mixed stock summer chum salmon run traveling up the mainstem Yukon River until July 18, at which time all chum salmon counted at the sonar are considered fall chum salmon. Although summer chum salmon undoubtedly migrate past the sonar after this time, it is assumed that fall chum salmon are more numerous. The Pilot Station sonar began operating in 1986 but changes in methods resulted in a discontinuous time series before 1996 (Lozori and McIntosh 2014). The Anvik River is one of the largest producers of summer chum salmon within the Yukon River drainage. The Anvik River sonar (rkm 579) started operating in 1979 and has been one of the longest continuously operated escapement monitoring projects for summer chum salmon (Buklis 1982). This sonar provides reliable escapement estimates for the Anvik River because it is relatively unaffected by environmental conditions that commonly impact salmon counts at other sonar sites such as high water, debris, and co-migrating species. The Anvik River sonar estimates of fish passage are considered more accurate than those from the Pilot Station sonar because they do not require species apportionment. The Anvik River is also relatively narrow at the sonar site at approximately 62 m, whereas the width of the Yukon River at the Pilot Station sonar site exceeds 1,200 m. The ability to accurately count summer chum salmon at Pilot Station sonar is hindered more often by high water, debris, and large runs of pink salmon (*Oncorhynchus gorbuscha*) or whitefish (*Coregonus* spp.).

Summer chum salmon returns to the Anvik River have dropped substantially since about 2002, from a historical average of approximately 686,000 fish in 1986–2002 to an average of about 444,000 fish in 2003–2013 (McEwen 2015). In contrast, the total summer chum salmon run past Pilot station sonar has generally remained strong, averaging about 1,349,000 fish in 1986–2002 and about 2,049,000 fish in 2003–2013 (Lozori and McIntosh 2014). Summer chum salmon escapement estimated by the Anvik River sonar has declined in proportion to estimated summer chum salmon passage at the Pilot Station sonar by about 4% per year over the 1986–2013 period. An important objective of the summer chum radiotelemetry project was to independently confirm the relationship between summer chum salmon passage estimates at the Anvik River and Pilot Station sonars. This would help to clarify whether the apparent decline in the Anvik River stock relative to the total run truly reflects a change in relative stock strengths, or results from any bias in either of the sonar estimates. Confirming the relationship between the Anvik River stock and the total run is important for establishing a benchmark against which to monitor the status of the Anvik stock in the future, especially if the Anvik sonar project may be discontinued.

Radiotelemetry was considered to be the best and most practical method to obtain information about Yukon River summer chum salmon stock size, run timing, distribution, and spawning habitat. Several telemetry studies have been conducted on other salmon species within the Yukon River basin. Studies from 1996 to 2001 demonstrated that large-scale radiotagging studies of fall chum salmon in the Yukon River basin were feasible (JTC 1996, 1998; Spencer et al. 2002) and large-scale radiotelemetry studies conducted between 2002 and2004 provided valuable information on the run characteristics of Chinook salmon in the Yukon River basin (Eiler et al. 2004, 2006a, 2006b). A small feasibility radiotagging study was conducted on summer chum salmon in the Yukon River in 2004 (concurrently with Chinook salmon radiotelemetry). Although relatively successful (Spencer and Eiler 2007), sample size was limited and definitive conclusions concerning run characteristics of individual summer chum stock groups were not obtained from that project. This document describes the first full scale radiotelemetry investigation of summer chum salmon in the Yukon River drainage. Radiotelemetry and mark–recapture methods were used to estimate stock specific run timing, travel rates, movement patterns, distribution, and drainagewide abundance of summer chum salmon above the village of Russian Mission.

OBJECTIVES

1. Estimate stock specific run timing, travel rates, and distribution of summer chum salmon.
2. Identify important spawning tributaries and establish a stock composition baseline using relative escapements to monitor stock productivity over time.
3. Identify migration routes and spawning areas that need to be added to the anadromous water catalog (AWC).
4. Use mark–recapture methodology to estimate summer chum salmon abundance above Russian Mission.
5. Use radiotelemetry results to evaluate the relationship between estimates of summer chum salmon passage at the Anvik River sonar and Pilot Station sonar.

METHODS

STUDY AREA

The Yukon River watershed exceeds 855,000 km^2, is the fourth largest drainage basin in North America, and discharges over 200 km^3 of water per year into the Bering Sea (Brabets et al. 2000). As the longest river in Alaska, the distance between the mouths of the Yukon River to its headwaters in British Columbia, Canada, is more than 3,000 km. All 5 species of Pacific salmon *Oncorhyncus* spp. enter the Yukon River to spawn each year.

The study area includes the mainstem Yukon River and its tributaries between rkm 167 at the Andreafsky River mouth and the drainage upstream of the tagging location (Figure 1). Fish capture and tagging occurred 29 km upriver from Russian Mission near the base of Dogfish Mountain (rkm 369). The Yukon River is confined to 1 relatively narrow channel in this location which allows for efficient capture of salmon with gillnets. Summer chum salmon escapement for the only major spawning tributary below Russian Mission, the East Fork Andreafsky River, is monitored using a weir and provides an index of lower river escapement outside the mark–recapture study area.

FISH CAPTURE AND TAGGING

Summer chum salmon were captured using modified drift gillnets that consisted of 4.5-inch mesh constructed of #21 cable-laid netting, 5.5-inch mesh constructed of #9 cable laid netting, and 6.0-inch mesh constructed of #9 cable laid netting. Each net was 20 fathoms long, 7.6 m deep, and hung at a 2:1 ratio. In 2014, the 4.5-inch mesh net was used throughout the season and the 5.5-inch mesh net was used from July 9 through July 13. All 3 nets were alternated daily during the 2015 season. The addition of the 6.0-inch mesh net was to allow for the capture of larger summer chum salmon in 2015.

Fish capture and tagging occurred from June 12–July 13 in 2014 and June 12–July 21 in 2015. Tagging schedules were developed preseason using historical run timing from the Pilot Station sonar project and were designed to cover over 95% of the run during a full season of deployment. The deployment schedule was modified inseason daily to deploy tags in proportion to actual summer chum salmon abundance as the run progressed, based on information from test fishery and sonar projects in the lower river (Appendix A1).

Two crews fished simultaneously each day to meet tagging goals. Each crew fished up to 7.5 hours per day, 7 days per week, until all tags were deployed. One end of the drift gillnet was attached to a crew boat at all times during fishing and the drift gillnet was retrieved from the water once it became apparent that a salmon was entangled in the net. All salmon were cut from the net and only the first 4 summer chum salmon were retained for evaluation and tagging. Every effort was made to live-release any additional fish. The first 4 fish captured were transferred directly to the boat with a dip net and placed in a submerged tagging cradle within an onboard holding container. The holding container was continuously re-supplied with fresh river water using a battery-powered bilge pump. All fish were handled as gently as possible to minimize stress. Injured or unhealthy fish were released alive back into the water and the 3 most vigorous fish were selected for tagging. Prior to tagging, the fish were measured and weighed. Length was measured from mid eye to tail fork (METF) to the nearest mm. Girth was recorded just anterior of the dorsal fin to the nearest mm. Fish were also placed directly onto an onboard scale and their weights were measured to the nearest tenth of a kg. Fish weights were not recorded in 2015 to shorten handling times. All data were recorded in electronic tablets programed with Microsoft Access[1] and sent electronically to a SQL Server Database in Fairbanks, AK.

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

Fish selected for tagging were implanted with an esophageal radio transmitter and a secondary external mark. Advanced Telemetry Systems model F1840B pulse-coded radio transmitters, in the 150–151 MHz frequency range, that were 5.4 cm long, 2.0 cm in diameter, and 22 g in weight were used. Transmitters were applied to fish through the mouth and into the stomach using a plastic tag applicator that was one quarter in diameter and approximately 9 in long. Each transmitter emitted a unique frequency-code combination that allowed for identification of individual fish. Transmitters also featured a built-in motion sensor and activity monitor to detect immobilization indicating the possibility of mortality. When no motion was detected for 24 hours, a code indicating lack of movement was transmitted. Those features made it possible to track movement and mortality of individual fish. Transmitters had a minimum battery life of 240 days. Secondary marks—unique and sequentially numbered 12-inch-long white spaghetti tags, Floy Tag and Manufacturing model FT-4—were sewn through the musculature at the base of the dorsal fin and secured using brass ferrules. Spaghetti tags were applied to make radiotagged fish more easily identifiable if encountered upriver and to estimate potential radio tag loss. All fish were released back into the water immediately after sampling.

Remote Stationary Tracking

Upstream movement of tagged summer chum salmon was monitored using an existing network of remote tracking stations, hereafter referred to as tracking stations (Eiler et al. 2004; Eiler et al. 2006a-b; Eiler et al. 2014). The tracking stations consisted of several integrated components attached to a Vaisala model 404A portable remote automatic weather station tower. Components included an Advanced Telemetry Systems computer-controlled receiver model R4500C, Campbell Scientific model 443A geostationary operational environmental satellite (GOES) transmitting antenna and SAT High Data Rate GOES satellite uplink, and a self-contained power system consisting of 2 Kyocera model KC80 solar panels and 6 Concorde Battery Corporation model PVX-2240T AGM batteries. The tracking stations were located along important migration corridors and spawning tributaries within the Yukon River drainage (Figure 1; Appendix A2). The first tracking station was located approximately 28 rkm downstream of the tagging site. Tagged salmon that traveled past this tracking station were considered “dropouts” that were probably negatively impacted by capture and handling. The first tracking station upriver of the tagging site, hereafter referred to as Paimiut Station, was placed 22 rkm upstream from the tagging site to monitor the initial movements of tagged fish and to determine which tagged fish recovered from handling and should be considered part of the marked population. Seven tracking stations were located on the mainstem Yukon River near the mouths of major tributaries. In addition, tracking stations were located within several major tributaries: 1 within the Innoko River, 2 within the Anvik River, 4 within the Koyukuk River, 1 within the Nowitna River, and 8 within the Tanana River. Signals from radiotagged fish within reception range of a given station were recorded with the following information: date and time the signal was recorded; signal strength and activity pattern of the transmitter (active or inactive), and location of the fish in relation to the station. Tracking station data were transmitted every hour to a GOES and relayed to a receiving station near Washington D.C. (Appendix A3). These data were then downloaded from the Washington D.C. receiving station to a Microsoft Access database at the Fairbanks ADF&G office.

AERIAL SURVEYS

Aerial surveys were used to determine the distribution of tagged summer chum salmon within non-terminal mainstem areas and in otherwise unmonitored major tributaries within the Yukon River drainage (Appendix A4). These surveys took place from fixed-wing aircraft and helicopters equipped with 4-element Yagi-type receiving antennas. Radio transmitter signal strength increases substantially when tags are not submerged in water; thus, tags located in association with villages or fish camps that had high signal strengths were recorded as caught but not returned. Survey flight routes were determined by analyzing passage records from tracking stations using a crosstab query in the SQL database to verify where to focus aerial survey effort. Tributaries without tracking stations were surveyed if they were located near the last recorded location for tagged fish. As aerial survey data was returned and loaded into the database, additional analysis was conducted to identify fish that may have been unaccounted for within those sections of river. Efforts were made to fly the mainstem Yukon River periodically throughout the duration of the study, and tributaries not monitored by tracking stations were flown when logistically feasible to maximize coverage. Tributaries with tracking stations were flown less often to reduce costs and tracking flights were combined with routine management surveys where possible. Boat tracking was also conducted near the tagging site to locate possible regurgitated tags, which were usually found within close proximity to the tagging area. In 2014 and 2015, there were 43 and 32 aerial surveys flown, respectively.

RECAPTURE SAMPLING AND TAG RECOVERY

Recapture sampling was conducted at escapement counting projects (weirs, towers) where all passing fish could be examined for presence of a tag, either visually (weir) or by means of a radio telemetry receiver (tracking station). The complete passage count and number of tagged fish within that passage were used to determine the marked fraction in the pooled Chapman's modified Petersen estimates (Seber 1982). Projects monitoring salmon escapement upstream of the tagging site at Russian Mission included the following the Anvik River sonar (rkm 507, from mouth of Yukon); Gisasa River (rkm 1,046) and Henshaw Creek (rkm 1,809) weirs in the Koyukuk River drainage; Chena River sonar/counting tower (rkm 1,481) and Salcha River counting tower (rkm 1,553) in the Tanana River drainage (Figure 1). In addition to visual inspection for tagged fish, radiotelemetry receivers equipped with 4-element Yagi-type receiving antennas were placed at the Gisasa River and Henshaw Creek weirs to monitor the total number of tagged fish that passed by the weir sites.

Radio tags were also tracked, but were not included in mark–recapture samples, at several additional monitoring projects, including the test fishery sampling at the mainstem Tanana River sonar near Manley (rkm 1,224) and the East Fork Andreafsky River weir (rkm 208). The latter monitored for marked fish moving downstream from the tagging site. To facilitate return of tags caught in fisheries, informational posters describing the study, emphasizing the importance of reporting, and explaining how to report tags caught during a fishery were distributed in numerous villages prior to the start of tagging project (Appendix A5). Radio tags that were returned to ADF&G by fishermen inseason were redeployed when possible.

DATA ANALYSIS

Data Processing

As fish migrated up the Yukon River their attached radio tags constantly emitted a frequency-code combination that uniquely identified them. As tagged fish approached a tracking station, the tracking station recorded the data encoded in the signal, applied a timestamp to it, and stored the record. Data were sent via satellite to the local readout ground station (LRGS) data collection facility on Wallops Island, Virginia each hour. Both the GOES network and the LRGS are operated by the National Oceanic and Atmospheric Association (NOAA) and ADF&G was allotted specific time bands to make data transmissions. Finally, GOES Downloader software was used to download and decode the data from the LRGS into an ADF&G database. Within the database, multiple raw records from a given transmitter were reduced to a single record representing a passage of a tagged fish at a given tracking station.

A Microsoft SQL Server Express database was used to aggregate and store the data from tagging, tracking stations, and aerial surveys. Tagging data consisted of a record for every tagged fish and a record for every fishing event. The movement data consisted of a large number of raw records due to migration variation noted for fish traveling upriver. Tagged fish may linger or die near a tracking station and produce records for weeks at a time; however, attempts were made to identify and censure these tags from the database. Several steps were required for the generation and storage of movement data. Because fish tend to meander back and forth between the upstream and downstream tracking station antennas while traveling upriver, only the highest signal strength recorded on the upstream antenna was used as a crossing point. If the fish passed that point, retreated downstream, and then again crossed the upstream antenna, only the first crossing was used as the passage. The time fish spent upstream and downstream, while still near the tower but after the first crossing, was counted into its travel time to the next tower. To facilitate this process, the Passage Picker[2] program was created, which assisted automatic and manual manipulation of the thousands of raw tower records. Outlier analysis was necessary to avoid including records from fish harvested and then transferred in boats or planes that might grossly inflate travel rates or distort other estimates. This was performed by reviewing the tracking station crossings for each fish to ensure the chronological progression was consistent with the geography of the river. Queries from the database were imported into R Statistical Software[3], which was used to summarize the data for stock timing, travel rates, and the proportion of radio tags entering final spawning locations.

Catch Per Unit Effort

The summer chum salmon catch for each drift was converted to a drift CPUE; i.e., number of summer chum salmon caught per fathom hour.

We denote that:

i = fishing date;

m = mesh size (4.5, 5.5, or 6.0 in stretch mesh);

$f_{i,m}$ = net length;

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[2] Created by Cody Gossel and Rich Driscoll, Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks, AK.

[3] The R Project for statistical computing. R version 2.15.1 (Roasted Marshmallows). [released: June 22, 2012; Cited: July 15, 2012]. Available for download from http://www.r-project.org/.

$t1_{i,m}$ = time of starting net deployment;

$t2_{i,m}$ = time of net fully deployed;

$t3_{i,m}$ = time of starting net retrieval;

$t4_{i,m}$ = time of net fully retrieved; and

$C_{i,m}$ = the number of summer chum salmon caught in each drift.

For each drift, mean fishing time was calculated as:

$$\bar{T}_{i,m} = \frac{1}{2}(t3_{i,m} + t4_{i,m} - t2_{i,m} - t1_{i,m}) \ , \tag{1}$$

and its standardized drift CPUE ($I_{i,m}$) per fathom net length and hour of fishing effort was calculated as:

$$I_{i,m} = \frac{C_{i,m}}{f_{i,m} \cdot \bar{T}_{i,m}} \ . \tag{2}$$

To provide an estimate of relative abundance of summer chum salmon passing the tagging sites, a daily CPUE(I_i) was calculated as:

$$I_i = \sum I_{i,m} \ . \tag{3}$$

CPUE was compared to summer chum salmon passage at the Pilot Station sonar, lagged by estimated travel time to the tagging site, to determine the effectiveness of the tagging schedule during 2014 and 2015. Additionally, a comparison of CPUE and daily tag deployment was used to further evaluate the effectiveness of the tag application.

Stock Specific Run Timing, Travel Rates, and Distribution

Fish tracked to terminal tributaries were judged to have reached their final destination and were designated as part of the stock associated with that tributary. Stock specific run timing was estimated as the average date tagged fish from each stock were first encountered and tagged at the tagging site.

Travel rates (kilometers per day) were determined for individual fish that traveled between the first tracking station, Paimiut Station, and upriver tracking stations. Fish passage time at each tracking station was the time when the radio tag signal was strongest as it shifted from the downriver antenna to the upriver antenna. Travel rates were estimated as the distance traveled between tracking stations divided by the time it took to travel between tracking stations. Distance traveled was estimated based on the assumption that fish traveled along the river’s thalweg (Eiler et al. 2014). Average travel rates were calculated for fish returning to geographic regions of the Yukon River (lower river, upper Koyukuk River, and Tanana River) and for individual tributaries (stock groups). Travel rates were compared for fish passing tracking stations within geographic regions of the Yukon River drainage using analysis of variance (ANOVA) and Tukey’s honest significant different test (Tukey HSD). The lower river region encompassed the Bonasila, Anvik, Innoko, Nulato, Gisasa, and Melozitna rivers, the upper Koyukuk River region encompassed the Hogatza and upper Koyukuk rivers, and the Tanana River region encompassed the Chena and Salcha rivers and the Tanana River mainstem. Travel rates within the mainstem Yukon River were also compared to travel rates within tributaries to characterize migration behavior as summer chum salmon approached their spawning destination. Average travel rates did not include travel between the tagging site and Paimiut station, in case tagging or capture affected initial travel speeds.

The distribution of summer chum salmon within the Yukon River drainage was estimated as the ratio of radiotagged salmon located within a specific reach (i.e., tributary or non-terminal area) to the total number of radiotagged salmon located within all tributaries or non-terminal areas. For a given reach (*j*) the proportion of summer chum salmon migrating to that reach ($P_{j,}$) was estimated using the following equation, where R*ij* was the number of fish tagged on day (*i*) having fate (*j*):

$$\hat{P}_j = \frac{\sum_{i}^{days} R_{ij}}{\sum_{j}^{fates}\sum_{i}^{days} R_{ij}}. \quad (4)$$

Variance was estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). Each bootstrap replicate drew a random sample from the total number of radio transmitters. From each of 1,000 bootstrap replicates, the proportion of spawners with spawning fate *j* ($\hat{P}^*_j$) was calculated. Finally, $\hat{P}_j$ was estimated as the average of all ($\hat{P}^*_j$) replicates and standard deviation was estimated across all ($\hat{P}^*_j$) replicates.

Two assumptions should be met to obtain unbiased estimates of spawning distribution. The first assumption is that tagging will not affect summer chum salmon migratory behavior. This was partially addressed by censuring fish that did not travel upriver past Paimiut Station. Although there is no direct test for delayed migratory impacts from tagging, Savereide (2005), Stuby (2006), and Spencer and Eiler (2007) have determined that handling delay can be negligible. Therefore, we assumed that there were no changes to migratory behavior from tagging and capturing procedures between Paimiut Station and upriver tributaries. The second assumption is that summer chum salmon are sampled and tagged in proportion to the magnitude of the run. To meet this assumption, each radiotagged salmon was given a numerical weight that incorporated differences in the probability that an individual fish was tagged during the marking event. Tagging probabilities were based on tag output and estimates of summer chum salmon abundance passing the tagging site. Estimates of summer chum salmon abundance were based on passage estimates at the mainstem Yukon River sonar site near Pilot Station. The summer chum salmon passage estimates from the sonar site were then lagged by estimated travel time to the tagging site. Tagging probabilities were estimated across 5 tagging strata. These strata were based upon pulses of summer chum salmon passage at the Pilot Station sonar, such that each stratum included a distinct summer chum salmon pulse observed at the sonar. A pulse was defined as a period of time when salmon passage estimates were high relative to passage estimates immediately before and after it. Weights for each stratum (w_k) were calculated as:

$$w_k = \frac{\sum_{k=1}^{5} x_k}{\sum_{k=1}^{5} \hat{A}_k} \div \frac{x_k}{\hat{A}_k}, \quad (5)$$

Where $\hat{A}_k$ is the estimated abundance of salmon that migrated past the tagging site during stratum (k); and x_k is the number of radio transmitters deployed during stratum (k).

A daily weight ($w_{i \in k}$) was applied for each day (i) within stratum (k) to estimate the number of fish tagged on day (i) having fate (j) where:

$$R_{ij}^{*} = R_{ij} \times w_i \,. \tag{6}$$

The weighted estimate of fish tagged each day (R_{ij}^{*}) was substituted for R_{ij} in Equation 4.

Mark–Recapture Assumptions

The natural variation inherent in salmon migrations and spawning escapements presents many possibilities for capture probabilities to vary. The summer chum salmon run within the Yukon River drainage presents even more complexity, because it is composed of different stocks that migrate into different tributaries and have different migration timing, routes, distances, and travel rates, and may also have different physical fitness at the tagging site. These differences among stocks cannot be corrected for during tagging. In addition, possible tagging or capture effects on behavior and survival of summer chum salmon could influence mark–recapture estimates if significant mortality or behavior modification occurs. Efforts were made to minimize handling and stress when capturing and tagging fish and the chosen tag size is believed to minimize impact on summer chum salmon. Assessment projects, tracking stations, and boat and aerial surveys downstream from the tagging site were used to monitor potential migration downstream after capture and tagging.

Assumptions associated with pooled Chapman's modified Petersen estimate include the following

1) The population is closed; i.e., there is no immigration or emigration into the population between sampling events;
2) Tagging does not affect the likelihood for a fish to be captured during second event sampling;
3) Fish do not lose their marks and all marks are recognized; and,
4) At least 1 of the following 3 conditions must be met: a) all fish have an equal probability of capture in the first sample (tagging); b) all fish have an equal probability of capture in the second sample; and c) fish mix completely between the first and second samples (Seber 1982, p.59; Pollock et al. 1990).

Assumptions (1–3) were tested through critical examination of movement and recovery data for tagged summer chum salmon and only tagged fish that successfully migrated upriver of Paimiut Station were used for mark–recapture abundance estimation. In addition, any fish caught in the fishery above Paimiut Station but below the recapture sites were censured from the experiment. Assumption (4) was tested after separating tagging data into 5 strata, based upon peak periods or pulses of the summer chum salmon run passing the Pilot Station sonar (Tables 1 and 2). In 2014, only the Anvik River sonar was used for recapture information but in 2015, the Anvik River sonar and the Gisasa River weir were used for recapture. Contingency tables using a chi-square statistic of homogeneity were used to test for equal probability of capture across tagging strata (time) and for equal recapture probability across recapture sites (Anvik and Gisasa rivers; Seber 1982; Arnason et al. 1996). If the goodness of fit test failed to show that equal capture probability assumption was violated, data from all tagging strata could be pooled. In that event, we would be able to estimate drainagewide abundance above Russian Mission using a pooled Chapman's modified Petersen estimate. In addition, because capture probability may be dependent on fish size, the cumulative length frequency distribution of radiotagged salmon was compared to the distribution from all summer chum salmon sampled at various projects. A Kolmogorov-Smirnov 2 sample test was used to test for homogeny between the 2 distributions.

Mark–Recapture Abundance Estimate

Mark–recapture methods were used to estimate summer chum salmon abundance above the first tracking station, Paimiut Station. Microsoft Excel was used to calculate the pooled Chapman's modified Petersen estimate (Seber 1982) each year, as follows:

$$\hat{N} = \frac{(\hat{C}+1)\times(M+1)}{R+1} - 1, \tag{7}$$

where $\hat{N}$ is the estimated abundance upriver of Paimiut Station; M is the number of radiotagged fish that survived handling and tagging and successfully migrated upriver past Paimiut Station; $\hat{C}$ is the estimated number of fish "inspected" at recapture sites; and R is the number of fish "inspected" at recapture sites that were also radiotagged.

A 2-stage parametric bootstrap simulation was used to estimate variance and statistical bias in the pooled Chapman's modified Petersen estimate, based on simulated replications of the mark–recapture experiment (Efron and Tibshirani 1993). The distribution of the number of marked and recaptured fish was modeled, denoted in subsequent equations with an asterisk (*), and separate estimates of abundance were calculated for each of 1,000 bootstrap replicates. A new simulated abundance estimate ($N^*_{(b)}$) was calculated with each bootstrap replicate, where b denotes an individual replicate, as follows:

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

where the number of tagged fish that moved upstream past Paimiut Station was assumed to have a binomial distribution (*BN*). We let T equal the total number of tags available to deploy, and p equals the proportion of tags that were deployed and successfully traveled upriver past Paimiut Station. For each bootstrap replicate, the population of tagged fish above Paimiut Station was modeled as:

$$M^*_{(b)} = BN(T, p). \tag{10}$$

The tagged fish that traveled upriver past Paimiut Station were assigned the following fates ($i = 0,\ldots, 4$):

(1) did not travel upriver past Paimiut Station (p_0);

(2) traveled upriver to non-recovery areas or were harvested (p_1);

(3) moved upriver past the Anvik River sonar (p_2); and

(4) moved upriver past the Gisasa River weir (p_3).

The total number of fish recovered was then modeled as:

$$R^*_{(b)} = \sum R^*_{(b)i+2}. \tag{11}$$

With each replicate a new simulated abundance estimate was generated (Equation 8), and after generating 1,000 bootstrap replicates (*B*), the final estimate of abundance was estimated as:

$$\overline{N}^{*} = \frac{\sum N^{*}_{(b)}}{B}. \tag{12}$$

Variance for the mark–recapture abundance estimate was calculated as:

$$v(\hat{N}) = \frac{\sum_{(b)}(N^{*}_{(b)} - \overline{N}^{*})^{2}}{B-1}, \tag{13}$$

and the relative statistical bias (*RBS*) was calculated as:

$$RBS = \frac{\hat{N} - \overline{N}^{*}}{\overline{N}^{*}} \times 100. \tag{14}$$

A drainagewide estimate of summer chum salmon abundance was calculated by adding together the mark–recapture abundance estimate above Paimiut Station, the subsistence and commercial harvest below Paimiut Station, and the escapement into the Andreafsky River. Only the east fork of the Andreafsky River is monitored for summer chum salmon abundance; however, it is assumed that doubling the escapement into the East Fork Andreafsky River accurately represents escapement into the entire Andreafsky River system (which includes a west fork of similar volume).

Evaluating Relationship between Estimates of Summer Chum Salmon Passage at the Anvik River Sonar and Pilot Station Sonar

We compared fish passage at the sonars to our telemetry data to evaluate the relationship between estimates of summer chum salmon passage at the Anvik River sonar and Pilot Station sonar. First, we calculated the percentage of fish that migrated past the Pilot Station sonar that also migrated past the Anvik River sonar (Anvik River sonar estimate / Pilot Station sonar estimate). Second, we calculated the percentage of tagged fish that successfully migrated past Paimiut Station that traveled past the Anvik River sonar. Finally, we qualitatively compared the 2 percentages; agreement between the 2 percentages would confirm the true relationship between the sonar passage estimates. Although tagging occurred approximately 100 river miles upriver of the Pilot Station sonar, the comparison between sonar and telemetry data was deemed appropriate because we assumed there was relatively little spawning occurred between the 2 locations.

NOMINATIONS TO ANADROMOUS WATERS CATALOG

The final locations of each tagged summer chum salmon were compared to known summer chum salmon spawning habitat outlined in ADF&G's AWC. All tagged fish that entered streams not already recognized as summer chum salmon habitat in the AWC were identified. New migratory or spawning locations and extension of ranges determined from this project were submitted to ADF&G Division of Habitat for nomination for inclusion within the AWC.

RESULTS

FISH CAPTURE AND TAGGING

Drift gillnets were fished between June 12 and July 13, 2014 to capture 1,705 summer chum salmon (Table 3; Appendix A1). Daily CPUE ranged from 0.09 fish per fathom-hour on July 12 to 1.05 fish per fathom-hour on July 4. In addition, daily CPUE and tag deployment matched up well with daily passage estimates at the Pilot Station sonar (Figure 2). Two summer chum salmon were killed during capture and kept for subsistence purposes. A total of 1,232 fish were marked with radio and spaghetti tags; 298 (24%) were male and 925 (75%) were female and sex was unidentifiable for 9 fish. Male fish were an average of 580 mm in length, 346 mm in girth, and weighed about 3 kg, whereas female fish were 537 mm in length, 305 mm in girth, and weighed about 2 kg (Table 4). Thirty-four radio tags were caught by fishermen upriver and returned for redeployment.

Drift gillnets were fished between June 12 and July 21, 2015, to capture 2,257 summer chum salmon (Table 3; Appendix A1). Daily CPUE ranged from 0.09 fish per fathom-hour on July 16 to 3.50 fish per fathom-hour on July 1. Similar to 2014, daily CPUE and tag deployment matched well with daily passage estimates at the Pilot Station sonar (Figure 3). A total of 1,199 fish were marked with radio and spaghetti tags, of which 625 (52%) were male and 562 (47%) were female; sex was unidentifiable for 12 fish. Male fish were an average of 582 mm in length and 345 mm in girth, whereas female fish were 551 mm in length and 318 mm in girth (Table 5).

RECAPTURE SAMPLING AND TAG RECOVERY

In 2014, out of the 1,232 tagged summer chum salmon, there were 3 mortalities, 22 tag malfunctions, 11 tag regurgitations, and 115 tagged salmon that remained in or traveled to spawning locations in the mainstem Yukon River below Paimiut Station. As a result, 1,081 tagged summer chum salmon migrated past Paimiut Station and entered the marked population within the study area of the mark–recapture abundance experiment (Table 3; Figure 4). Of the marked population, 781 fish (72%) were tracked to tributaries off the mainstem Yukon River by stationary or aerial survey receivers, 217 (20%) were tracked to locations along the mainstem Yukon River, and 83 (8%) were caught in fish wheels near Kaltag (management Subdistrict 4-A; Figure 6). Only 2 tagged salmon were physically observed at a monitoring and assessment project site (Gisasa River weir).

In 2015, out of the 1,199 tagged summer chum salmon, there were 25 tag malfunctions, 15 tag regurgitations, and 109 fish that traveled to spawning locations, or remained in the mainstem Yukon River, below Paimiut Station. As a result, 1,050 tagged summer chum salmon migrated past Paimiut Station and entered the marked population within the study area (Table 3). Of the marked population, 879 fish (84%) were tracked to tributaries off the mainstem Yukon River, 161 (15%) were tracked to locations along the mainstem Yukon River, and 10 (1%) were caught by fishermen (Figure 5). Ten radiotagged fish were observed at the Gisasa River weir and 23 tagged fish were observed at the Henshaw Creek weir.

STOCK SPECIFIC RUN TIMING, TRAVEL RATES, AND DISTRIBUTION

Run timing was highly variable among summer chum salmon stocks. Koyukuk River summer chum salmon tended to enter the Yukon River earlier than fish from the Anvik and Bonasila rivers (Figures 6 and 7). In 2014, mean run timing for tagged fish from the Koyukuk River stock passing Russian Mission was June 23, and mean run timing for tagged fish from the Bonasila and Anvik river stocks was June 28 (Table 6). In 2015, tagging results indicated that mean run timing for Koyukuk River stocks passing Russian Mission was June 27, mean run timing for the Bonasila River was June 30, and mean run timing for the Anvik River was July 1 (Table 7). Encounters at the tagging site with Anvik River fish peaked on June 27 in 2014 and June 30 in 2015 and, for both years, few Anvik River fish were encountered at the tagging site during the tail ends of the run (Figures 8 and 9). Tanana River stocks were encountered at the tagging site intermittently through the tagging seasons (Figures 8 and 9). Summer chum salmon stocks located near or below the tagging site at Russian Mission (i.e., Kako Creek and Innoko River) had some of the latest run timing (Tables 6 and 7).

Travel rates for radiotagged summer chum salmon varied across stocks and geographic regions of the Yukon River drainage in 2014 and 2015. The highest rates were associated with fish returning to the upper Koyukuk River (mean of 50.0 km/day in 2014 and 57.6 km/day in 2015) and the lowest rates associated with fish returning to the Anvik River (mean of 28.6 km/day in 2014 and 27.7 km/day in 2015; Tables 8–12). Travel rates also varied within stocks depending on the stage of spawning migration; mean travel rates were faster within the mainstem Yukon River and slower within tributaries off the mainstem Yukon River (Tables 8–12). The mean travel rate of tagged fish returning to the upper Koyukuk River region was significantly faster than that of fish traveling to the lower river or Tanana River regions in 2014 and 2015 (ANOVA; Tukey HSD; $p < 0.01$; Tables 10 and 13). In addition, travel rates were faster during the first half of the summer chum salmon run and slower during the second half of the run in 2014 and 2015 (Tables 14 and 15).

Over 70 aerial surveys were conducted between June and August in 2014 and 2015, which produced thousands of records of tagged summer chum salmon. Tagged summer chum salmon entered more than 25 primary tributaries to the Yukon River each year from directly below the tagging site to the upper reaches of the Koyukuk and Tanana rivers (Tables 16 and 17; Figures 10 and 11). In 2014, 998 (81%) tagged fish successfully migrated upriver past Paimiut Station, avoided fishery capture, and were successfully tracked to various reaches within the Yukon River drainage. Of those, approximately 11% entered the Bonasila River, 21% entered the Anvik River, and 22% entered the Koyukuk River (Figure 12). In 2015, 1,040 (87%) tagged fish successfully migrated upriver past Paimiut Station, avoided fishery capture, and were successfully tracked to various reaches within the Yukon River drainage. Of those, approximately 9% entered the Bonasila River, 21% entered the Anvik River, and 27% entered the Koyukuk River (Figure 13). Tagged fish had a wide distribution within spawning streams (Figures 14–22).

MARK–RECAPTURE ABUNDANCE ESTIMATE

Tests of Assumptions

The closed population assumption (1) was probably met for several reasons. Emigration or deaths were probably inconsequential because fish that did not remain upriver of Paimiut Station or were suspected caught in a fishery were censured from the mark–recapture experiment and all tagged fish that entered the study area were located through tracking efforts. Immigration was probably inconsequential because each fish that entered the study area must have traveled through the tagging site and tagging occurred throughout the majority of the summer chum salmon runs. The likelihood for recapture assumption (2) was not directly testable; however, it was probably met because successful tracking of tagged fish indicated that the effects of tagging on mortality or migration behavior were negligible. Sluggish behavior and slower travel rates were observed immediately after release, which we assumed due to tagging and handling effects, but rates increased dramatically once the fish traveled above Paimiut Station. Although not directly testable, the tag loss assumption (3) was probably met because all tagged fish not located moving upstream past Paimiut Station were censored from the experiment.

Equal probability of capture in the first sample (tagging)—i.e., condition (a) of Assumption (4)—was tested in 2014 and 2015. We used contingency tables to test for consistency in capture probability across tagging strata, which indicated there were no significant temporal changes in capture probabilities (chi square; $p = 0.11$ in 2014, $p = 0.45$ in 2015; Tables 1 and 2). As a result, the pooled Chapman's modified Peterson estimate was deemed appropriate for the mark–recapture analysis.

The test for equal recapture probability across recapture sites did not occur in 2014 because poor water conditions resulted in incomplete or missing summer chum salmon counts at all monitoring projects except the Anvik River sonar. Comparison of marked fractions across recapture locations in 2015 (Anvik River sonar, Gisasa River weir, and Henshaw Creek weir) indicated that fish did not have an equal chance of being tagged downriver ($\chi^2 = 94.64$, df = 3, $p < 0.01$; Table 18). However, comparison of marked fractions indicated that fish recaptured at the Anvik River sonar and Gisasa River weir had an equal chance of being tagged downriver ($\chi^2 < 0.01$, df = 2, $p = 0.50$; Table 18). Fish returning to Henshaw Creek had a much lower probability of being caught and tagged at Russian Mission than fish returning to the Anvik and Gisasa rivers. Including Henshaw Creek as a recapture site in 2015 would have substantially inflated our mark–recapture abundance estimate and compromised the project that year. Thus, only the Anvik River sonar was used for recapture information in 2014 and the Anvik River sonar and the Gisasa River weir were used for recapture information in 2015.

The length frequency distributions differed between tagged summer chum salmon and summer chum salmon encountered at upriver assessment projects. In 2014, tagged fish were decidedly smaller than fish examined at the Anvik River sonar (Kolmogorov-Smirnov test; $D = 0.39$; $p < 0.01$). Similarly, tagged fish in 2014 were smaller than fish examined at the Gisasa River weir (Kolmogorov-Smirnov test; $D = 0.26$; $p < 0.01$; Figure 23). In 2015, however, tagged fish were larger than fish examined at the Anvik River sonar (Kolmogorov-Smirnov test; $D = 0.15$; $p < 0.01$). Tagged fish were larger than fish examined at the Gisasa River weir (Kolmogorov-Smirnov test; $D = 0.17$; $p < 0.01$). Tagged fish were also larger than fish examined at the Henshaw Creek weir (Kolmogorov-Smirnov test; $D = 0.13$; $p < 0.01$; Figure 24).

Mark–Recapture Abundance Estimation

Recovery information (second event sampling) needed for mark–recapture abundance estimation came from the Anvik River in 2014 and from the Anvik and the Gisasa rivers in 2015. In 2014, the pooled Chapman's modified Peterson estimate of summer chum salmon abundance upstream of Paimiut Station was approximately 2,100,000 (SE = 130,000) fish and a relative statistical bias of 0.03% (Figure 25). This estimate was based on 1,081 marked fish in the first sample, and 399,796 inspected fish; 204 fish had tags in the second sample (Table 18). In 2015, the pooled Chapman's modified Petersen estimate of summer chum salmon abundance upstream of Paimiut Station was approximately 2,100,000 (SE = 130,000) fish and a relative statistical bias of 0.36%

(Figure 26). This estimate was based on 1,050 marked fish, 417,715 inspected fish, and 206 recaptured fish (Table 18).

The total drainagewide summer chum salmon abundance was approximately 2,700,000 fish in 2014 and 2,600,000 fish in 2015. This estimate uses the pooled Chapman's modified Petersen estimate for the number of fish above Paimiut Station, the commercial and subsistence harvests below Paimiut Station, and the escapement into the Andreafsky River (Table 19). No tagged fish were reported caught in fisheries between Paimiut Station and the recovery sites.

EVALUATING RELATIONSHIP OF ANVIK RIVER SONAR TO THE PILOT STATION SONAR

The Anvik River sonar was operated from June 17 to July 26 in both 2014 and 2015. In 2014, the sonar recorded a cumulative summer chum salmon passage of 399,796 fish, representing about 20% of the summer chum salmon passage observed at the Pilot Station sonar (2,020,309 fish). Similarly, about 19% of the tagged summer chum salmon migrated past the Anvik River sonar to spawn (204 tags out of 1,081). In addition, the Anvik River sonar summer chum salmon estimate was about 15% of the Yukon drainagewide estimate produced through radio telemetry and mark–recapture. In 2015, the Anvik River sonar recorded a cumulative summer chum salmon passage of 374,968 fish, which was 24% of the total summer chum salmon passage observed at the Pilot Station sonar (1,591,505 fish). The proportion of tagged summer chum salmon that migrated past the Anvik River sonar was smaller at about 18% (185 tags out of 1,050). The Anvik River sonar summer chum salmon estimate was about 14% of the Yukon drainagewide estimate produced through radiotelemetry and mark–recapture.

NOMINATIONS TO ANADROMOUS WATERS CATALOG

In 2014, 106 tagged summer chum salmon traveled to streams that were not listed in the AWC as summer chum salmon spawning habitat. This resulted in 23 revisions to the AWC, including the addition of 13 new spawning streams for summer chum salmon. In addition, 8 streams were classified as "back-up", given the need for additional observations of salmon to meet the minimum requirements for AWC nominations. Most notably, the Huslia River and Billy Hawk Creek, each within the Koyukuk River drainage, received a relatively large number of tagged fish and were previously not listed as summer chum salmon spawning habitat in the AWC (Table 20). Nominations to the AWC from the tagging and tracking effort that took place in 2015 have been submitted and outcomes from those nomination submissions will be available during spring 2017.

DISCUSSION

Summer chum salmon capture and tagging near Russian Mission were effective. Daily tagging CPUE closely matched passage at Pilot Station sonar. Unfortunately, size-selective fishing resulted in the capture and tagging of fish with below-average lengths and, consequently, more females in 2014. Radiotagged fish were an average of 20 mm longer in 2015 after the addition of larger mesh gillnets. About 95% – 97% of tagged summer chum salmon successfully traveled upriver past Paimiut Station or entered streams near the tagging site during the study. These percentages are comparable with those from radiotelemetry studies for Yukon River Chinook salmon tagged near Russian Mission, where about 97% of tagged fish resumed upriver movements after tagging (Eiler et al. 2014). This suggests that capture and handling effects may have had a minimal impact on the summer chum salmon spawning migration. Although efforts were made to catch summer chum salmon on both banks of the Yukon River, most salmon were caught on the right bank, which is probably a more sufficient migration corridor than the left bank, which was relatively shallow, with a gradual bottom profile.

Summer chum salmon run timing showed clear migratory patterns that were consistent across years for some stocks. For example, summer chum salmon returning to the Koyukuk River were among the first fish to be encountered at the tagging site, and most migrated past the lower Yukon River before the midpoint of the run. Conversely, summer chum salmon returning to the lower Yukon River near the tagging site were among the last fish to be encountered. Two major stock groups, the Anvik and Bonasila river stocks, had protracted runs and peak passages at the tagging site near the midpoint of the run. Similar timing patterns were observed in Yukon River Chinook salmon. Lower basin stocks tended to enter the river later whereas major stocks groups returning to Canadian reaches and the Tanana River tended to have peak passages near the midpoint of the run (Eiler et al. 2006a).

We observed regional differences in summer chum salmon travel rates. Travel rates tended to increase with distance from mouth to spawning site and tended to be faster within the mainstem Yukon River and slower within tributaries off the mainstem. Fish returning to the upper Koyukuk River region traveled faster than fish traveling to the lower Yukon and Tanana River regions. Travel rates were slowest between the tagging site and Paimiut Station, probably because of a short-term recovery period or “sulking” after capture and tagging. Sulking immediately after tagging was also observed in radiotagged Yukon River Chinook salmon, but tagged salmon appeared to recover from handling effects within a few days (Eiler et al. 2014). Average travel rates for summer chum salmon within the mainstem Yukon River are comparable with the current assumed travel rate used for summer chum salmon management in the Yukon River (40.2 km/day); however, fish returning to the upper Koyukuk River region traveled notably faster than fish returning to other regions of the Yukon River drainage. This was similar to observations of regional differences in travel rates in radiotagged Chinook salmon, where travel rates tended to increase with migratory distance and decrease as salmon neared their spawning grounds (Eiler et al. 2006a; Eiler et al. 2014). There was some interannual variation in summer chum salmon travel rates between 2014 and 2015; travel rates were probably faster in 2015 because the average size of tagged fish was larger than in 2014.

Geographic distribution of summer chum salmon was similar during 2014 and 2015. Each year’s run was dominated by fish bound for 3 rivers; the Bonasila River, the Anvik River, and the Koyukuk River, which together comprised 54% of the tagged fish in 2014 and 57% of the tagged fish in 2015. Of the tagged fish that successfully migrated upstream of Paimiut Station, a relatively large number remained on or near the mainstem Yukon River. Some of these could have been fish last observed before reaching their spawning tributaries, fish spawning in smaller tributaries close to the mainstem Yukon River, or unreported harvests. However, some could also have been fish with delayed or altered migration due to handling stress. Stress can negatively impact the swimming performance and overall fitness of salmon (Schreck 1981; Schreck 2000) and the effects of stress may be delayed due to interactions with other sources of mortality (Budy et al. 2002). Interestingly, travel rates for summer chum salmon last observed within the mainstem Yukon River and summer chum salmon that successfully entered spawning tributaries were comparable. This suggests that handling stress probably had a minimal effect on migration speeds of summer chum salmon last observed in the mainstem Yukon River. Another possible explanation is that some salmon last observed in the mainstem could have later been harvested by fishermen and not reported. For example, aerial surveys could still pick up radio tag signals from tags that were regurgitated due to interaction with fishing gear or from radio tags that were discarded overboard by fishermen. Unreported tag recoveries by fishermen was suspected during Chinook salmon radiotelemetry studies on the Yukon River because a large number of tags were concentrated around villages or near fish camps (Eiler et al. 2006a). Similarly, some of the tagged summer chum salmon tracked to non-terminal reaches of the Yukon River were identified near areas with high fishing effort. If caught or regurgitated tags continue to be moved by a vessel or by the river current, then mortality signals would not be broadcasted. Although impossible to verify, we suspected that some tagged fish may have been caught in a fishery and not reported.

Summer chum salmon returning to the Tanana River generally arrive later in the run and were probably underrepresented during this study. Tagging during the end of the summer chum salmon run was challenging because of the presence of fall chum salmon which can be difficult to distinguish from summer chum salmon. Furthermore, the tagging schedule ended on July 13 in 2014 when a large portion of the Tanana River stock was still migrating through, being somewhat delayed by high water in that season. The capture and tagging data reflected this, where the highest daily proportion of Tanana River fish encountered at the tagging site occurred 1 day prior to the last tagging day. Only about 1% of tagged fish entered the Tanana River, but other information about the size of the Tanana River summer chum salmon stock (i.e., genetics mixed stock analysis for summer chum salmon sampled at the Pilot Station sonar) suggested the proportion would be higher (Estensen et. al. 2015b). In an attempt to better represent the summer chum salmon run, tagging crews operated until July 21 in 2015; however, Tanana River fish still accounted for only about 1% of tagged fish. Similarly, just over 200 radio tags were deployed during a feasibility summer chum salmon radiotagging study between June 8 and July 18, 2007, and no tagged fish entered the Tanana River (Spencer and Eiler 2007).

Meeting the assumption of equal probability of capture at the tagging site is important for an unbiased abundance estimate. To properly test this assumption, projects providing recapture sites must obtain complete estimates through the entire summer chum salmon run. High water conditions and debris caused projects to shut down periodically, end early, or not operate all season during 2014. In addition, so few tags entered the Tanana River that assessment projects on the Tanana River could not reasonably be included in the assumption testing. In 2015, however, the Anvik River sonar, Gisasa River weir, and the Henshaw Creek weir all remained operational during the summer chum salmon run. Although fish entering the Anvik and Gisasa rivers had similar ratios of marked-unmarked salmon, a much smaller ratio was observed at Henshaw Creek, which indicated that either fish were not tagged representative of the run or disproportionate numbers of tagged Henshaw fish failed to make it back to the spawning tributary. For example, tagged fish returning to Henshaw Creek may have been disproportionately affected by capture and handling due to Henshaw Creek’s distance from the tagging site and delayed negative effects from stress (Budy et al. 2002). Including Henshaw Creek as a recapture site would have introduced substantial bias into the mark–recapture experiment and inflated the total abundance estimate. In contrast, radiotelemetry studies on Chinook salmon in the Yukon River did not fail to meet the assumption of equal marked-unmarked ratio among various recapture sites; however, a much higher proportion of the overall Chinook salmon run was tagged during those studies (Spencer et al. 2006). For example, in 2004, about 0.64% of the Chinook salmon passage at the Pilot Station sonar were radiotagged, whereas in 2015, only 0.09% of the summer chum salmon passage at the Pilot Station sonar were radiotagged. The relatively small proportion of the summer chum salmon run that were radiotagged and the difficulty keeping upriver assessment projects operational for the duration of the summer chum salmon run made it difficult to test and meet mark–recapture model assumptions.

Radiotelemetry and sonar passage estimates were used to confirm the Anvik River's contribution to the total summer chum salmon run. In 2014, the proportion of the run assessed at Pilot Station sonar that then escaped into the Anvik River was similar to the proportion of tagged summer chum salmon that migrated past the Anvik River sonar, which provides confidence in the sonar and mark–recapture estimates produced that year. In 2015, however, fewer tagged fish migrated into the Anvik River than was expected based on sonar estimates. This discrepancy could have been due to an underestimation of summer chum salmon migrating past the Pilot Station sonar that year. The proportion of the total summer chum salmon run returning to the Anvik River is subject to change through time due to natural fluctuations of stocks that contribute to the total run. Information collected in 2014 and 2015 has provided an independent baseline or "benchmark" of that contribution, which will help in monitoring these fluctuations or changes in the future.

CONCLUSIONS

The ability to track individual radiotagged fish throughout their migration provided precise and detailed information on summer chum salmon spawning distribution, run timing, travel rates, and stock composition within the Yukon River drainage. The distribution data obtained through this study has produced a stock composition baseline that will allow managers to monitor for changes through time. Our results showed that several tributaries received a relatively high proportion of the summer chum salmon run and are currently unmonitored by any assessment projects. These tributaries include the Bonasila River, Thompson Creek, and Billy Hawk Creek. Managers should consider prioritizing the high use tributaries identified through this study if they decide to implement new monitoring projects within the Yukon River drainage. The run timing and travel rate information identified through this study will give managers the precision to account for individual summer chum salmon stocks as they migrate through fisheries management districts. Accounting for individual stocks when implementing harvest strategies would become exceedingly important if the run experiences declines in the future. Our results seemed to confirm the relationship between summer chum salmon escapement in the Anvik River and the total run. This relationship should continue to be monitored given the apparent declining contribution of the Anvik River run.

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REFERENCES CITED

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark–recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106.

Brabets, T. P., B. Wang, and R. H. Meade. 2000. Environmental and hydrologic overview of the Yukon River Basin, Alaska and Canada. U.S. Department of the Interior, U.S. Geological Survey.

Budy, P., G. P. Thiede, N. Bouwes, C. E. Petrosky, and H. Schaller. 2002. Evidence linking delayed mortality of Snake River salmon to their earlier hydrosystem experience. North American Journal of Fisheries Management 22:35–51.

Buklis, L. S. 1982. Anvik, Andreafsky and Tanana River salmon escapement studies, 1981. Alaska Department of Fish and Game, Yukon salmon escapement Report 15, Anchorage.

Brodersen, N. B., B. C. McIntosh, and C. T. Pfisterer. 2016. Feasibility of estimating salmon abundance in the Tanana River using sonar, 2012–2014. Alaska Department of Fish and Game, Fishery Data Series No. 16-36, Anchorage.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap. New York: Chapman & Hall.

Eiler, J. H., T. R. Spencer, J. J. Pella, M. M. Masuda, and R. R. Holder. 2004. Distribution and movement patterns of Chinook salmon returning to the Yukon River basin in 2000-2002. U.S. Department of Commerce NOAA Technical Memo NMFS-AFSC-148.

Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006a. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2003. U.S. Department of Commerce NOAA Technical Memo NMFS-AFSC-163.

Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006b. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2004. U.S. Department of Commerce NOAA Technical Memo NMFS-AFSC-165.

Eiler, J. G., M. M. Masuda, T. R. Spencer, R. J. Driscoll, and C. B. Schreck. 2014. Distribution, stock composition and timing, and tagging response of wild Chinook salmon returning to a large, free-flowing river basin. Transactions of the American Fisheries Society 143:6, 1476-1507.

Estensen, J. L., E. J. Newland, B. M. Borba, S. N. Schmidt, D. M. Jallen, and K. M. Hilton. 2015a. Annual management report Yukon Area, 2013. Alaska Department of Fish and Game, Fishery Management Report No. 15-19, Anchorage.

Estensen, J. L., S. N. Schmidt, S. Garcia, C. M. Gleason, B. M. Borba, D. M. Jallen, A. J. Padilla, and K. M. Hilton. 2015b. Annual Management Report Yukon Area, 2014. Alaska Department of Fish and Game, Fishery Management Report No. 15-50, Anchorage.

Flannery, B. G., T. D. Beacham, J. R. Candy, R. R. Holder, G. F. Maschmann, E. J. Kretschmer, J. K. Wenburg. 2010. Mixed-stock analysis of Yukon River chum salmon: application and validation in a complex fishery. North American Journal of Fisheries Management 30, 1324-1338.

Flannery, B. G., and J. K. Wenburg. 2014. Application of mixed-stock analysis for Yukon River chum salmon, 2012. Fisheries Resource Monitoring Program, Office of Subsistence Management, U.S. Fish and Wildlife Service, Annual Report for Study 10-205, Anchorage, Alaska.

REFRERENCES CITED (Continued)

Hamazaki, T., and J. M. Conitz. 2015. Yukon River summer chum salmon run reconstruction, spawner-recruitment analysis, and escapement goal recommendation. Alaska Department of Fish and Game, Fishery Manuscript Series No. 15-07, Anchorage.

Jallen, D. M., S. K. S. Decker, and T. Hamazaki. 2015. Subsistence and personal use salmon harvests in the Alaska portion of the Yukon River drainage, 2012. Alaska Department of Fish and Game, Fishery Data Series No. 15-28, Anchorage.

Johnson, J., and M. Daigneault. 2013a. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Interior Region, Effective July 1, 2013. Alaska Department of Fish and Game, Special Publication No. 13-07, Anchorage.

Johnson, J., and M. Daigneault. 2013b. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Western Region, Effective July 1, 2013. Alaska Department of Fish and Game, Special Publication No. 13-11, Anchorage.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 1996. Yukon River salmon season review for 1996 and technical committee report. Yukon River Joint Technical Committee, Whitehorse, Yukon Territory.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 1998. Yukon River salmon season review for 1998 and technical committee report, Yukon River Joint Technical Committee, Whitehorse, Yukon Territory.

JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2015. Yukon River salmon 2014 season summary and 2015 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A15-01, Anchorage.

Lozori, J. D., and B. C. McIntosh. 2014. Sonar estimation of salmon passage in the Yukon River near Pilot Station, 2012. Alaska Department of Fish and Game, Fishery Data Series No. 14-22, Anchorage.

McEwen, M. S. 2015. Anvik River sonar chum salmon escapement study, 2013. Alaska Department of Fish and Game, Fishery Data Series No. 15-08, Anchorage.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture recapture experiments. Wildlife Monograph 107.

Savereide, J. W. 2005. Inriver abundance, spawning distribution, and run timing of Copper River Chinook salmon in 2002. Alaska Department of Fish and Game, Fishery Data Series No. 03-21, Anchorage.

Schreck, C. B. 1981. Stress and compensation in teleostean fishes: response to social and physical factors. Pages 295–321 [*In*] A. D. Pickering, editor. Stress and fish. Academic Press, London.

Schreck, C. B. 2000. Accumulation and long-term effects of stress in fish. Pages 147–158 [*In*] G. P. Moberg and J. A. Mench, editors. The biology of animal stress. CAB International, Wallingford, UK.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, second edition. Charles Griffin and Sons, Ltd. London.

Spencer, T. R., R. S. Chapell, T. Hamazaki, and J. H. Eiler. 2002. Estimation of abundance and distribution of Chinook salmon in the Yukon River using mark–recapture and radiotelemetry in 2000 and 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-37, Anchorage.

Spencer, T. R., and J. H. Eiler. 2007. Movements of summer chum salmon radiotagged in the lower Yukon River in 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-71, Anchorage.

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2006. Mark–recapture abundance estimates for Yukon River Chinook salmon in 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-31, Anchorage.

Stuby, L. 2006. Inriver abundance of Chinook salmon in the Kuskokwim River, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 06-45, Anchorage.

TABLES AND FIGURES

Table 1.–The number of fish tagged (marked) that successfully entered the study area, the number of marked fish observed (recovered) or not observed (unseen) at the Anvik River sonar, and the estimate percent efficiency (recovered/marked) for tagging strata in 2014.

Stratum	Number of days	Marked	Recovered	Unseen	Percent recovered
6/12–6/17	6	85	10	75	11.8
6/18–6/24	7	304	45	259	14.8
6/25–6/30	6	388	77	311	19.8
7/1–7/5	5	170	40	130	23.5
7/6–7/13	8	134	32	102	23.9

Note: Each stratum included a summer chum salmon pulse traveling through Russian Mission, as determined by the passage at the Pilot Station sonar (3-day lag).

Table 2.–The number of fish tagged (marked) that successfully entered the study area, the number of marked fish observed (recovered) or not observed (unseen) at the Anvik River sonar or Gisasa River weir, and the estimate percent efficiency (recovered/marked) for tagging strata in 2014.

Stratum	Number of days	Marked	Recovered	Unseen	Percent recovered
6/12–6/18	7	76	11	65	14.5
6/19–6/27	9	276	54	222	19.6
6/28–7/5	8	409	80	329	19.6
7/6–7/12	7	178	44	134	24.7
7/13–7/21	9	111	17	94	15.3

Note: Each stratum included a summer chum salmon pulse traveling through Russian Mission, as determined by the passage at the Pilot Station sonar (3-day lag).

Table 3.–Number of summer chum captured; number and percentage of summer chum salmon tagged and numbers and percentages of tagged fish that died or regurgitated their tags, had tag malfunctions, remained downriver of Paimiut Station, or were caught in fisheries above Paimiut Station in 2014 and 2015.

	2014		2015	
Description	Number of fish	Percent	Number of fish	Percent
Total captured	1,705	–	2,257	–
Total tagged	1,232	100.0	1,199	100.0
Mortalities	3	0.2	0	0.0
Regurgitations	11	0.9	15	1.3
Tag malfunctions	22	1.8	25	2.1
Remained below Paimiut	115	9.3	109	9.1
Total entering study area	1,081	87.7	1,050	87.6
Caught in fishery above Paimiut	83	6.7	10	0.8
Total in study area	998	81.0	1,040	86.7

Note: En dashes indicate no value.

Table 4.–Mean, standard deviation (SD), and sample size (*N*) of length, girth, and weight for male and female summer chum salmon caught and tagged in 2014.

	Male			Female			
	N	Mean	SD	*N*	Mean	SD	*p*-value
Length (mm)	298	579.7	45.2	924	536.5	30.7	<0.000
Girth (mm)	292	346.3	37.1	918	304.6	25.5	<0.000
Weight (kg)	289	2.9	0.8	908	2.1	0.8	<0.000

Note: Significance values are from Welch Two Sample *t*-tests comparing length, girth, and weight between male and female summer chum salmon.

Table 5.–Mean, standard deviation (SD), and sample size (*N*) of length and girth for male and female summer chum salmon caught and tagged in 2015.

	Male			Female			
	N	Mean	SD	*N*	Mean	SD	*p*-value
Length (mm)	625	582.1	37.2	562	550.5	33.2	<0.000
Girth (mm)	624	345.0	29.3	562	318.2	29.7	<0.000

Note: Significance values are from Welch Two Sample *t*-tests comparing length and girth between male and female summer chum salmon.

Table 6.–Characteristics regarding run timing for summer chum salmon stocks captured near Russian Mission in 2014.

Stock	First fish	Last fish	Duration (Days)	Mean date	SD
Koyukuk River	6/12	7/10	29	6/23	5.8
Simon Creek	6/21	6/27	7	6/24	3.2
Nulato River	6/16	7/10	25	6/25	5.4
Ninemile River	6/22	6/29	8	6/25	3.5
Grayling Creek	6/21	6/29	9	6/26	3.6
Thompson Creek	6/15	7/13	29	6/26	6.1
Tanana River	6/17	7/12	26	6/26	7.2
Stink Creek	6/12	7/11	30	6/26	7.0
Rodo River	6/15	7/12	28	6/27	6.4
Bear Creek	6/16	7/11	26	6/27	6.0
Melozitna River	6/18	7/13	26	6/27	6.9
Kaltag River	6/16	7/08	23	6/27	5.7
Anvik River	6/13	7/13	31	6/28	6.6
Bonasila River	6/13	7/12	30	6/28	8.1
Blackburn Creek	6/26	7/03	8	6/29	3.3
Shovel Creek	6/29	6/30	2	6/29	0.7
Tozitna River	6/13	7/08	26	6/29	7.7
Yuki River	6/19	7/09	21	6/29	7.3
Koserefski River	6/29	7/01	3	6/30	1.4
Kako Creek	6/16	7/12	27	7/02	6.9
Tuckers Slough	6/26	7/09	14	7/03	4.3
Innoko River	6/29	7/10	12	7/04	7.8

Table 7.–Characteristics regarding run timing for summer chum salmon stocks captured near Russian Mission in 2015.

Stock	First fish	Last fish	Duration (Days)	Mean date	SD
Big Salt River	6/13	6/20	7	6/16	4.9
Ukawutni Creek	6/16	7/03	17	6/24	8.5
Tozitna River	6/14	7/13	29	6/26	7.5
Koyukuk River	6/12	7/21	39	6/27	7.9
Melozitna River	6/17	7/21	34	6/28	7.7
Khotol River	6/19	7/08	19	6/28	13.4
Thompson Creek	6/12	7/17	35	6/29	8.3
Nulato River	6/12	7/16	34	6/30	8.8
Bonasila River	6/13	7/20	37	6/30	8.0
Innoko River	6/14	7/16	32	6/30	8.7
Anvik River	6/12	7/21	39	7/01	8.4
Tanana River	6/20	7/16	26	7/01	8.7
Ninemile River	6/14	7/14	30	7/01	9.2
Rodo River	6/16	7/21	35	7/01	9.3
Kaltag River	6/30	7/10	10	7/02	3.8
Grayling Creek	6/20	7/18	28	7/03	14.1
Simon Creek	6/27	7/11	14	7/03	4.7
Stink Creek	6/15	7/20	35	7/04	8.3
Bear Creek	6/22	7/21	29	7/04	7.1
Blackburn Creek	7/01	7/17	16	7/05	5.6
Kako Creek	6/18	7/21	33	7/06	8.6
Lockwood Creek	6/19	7/21	32	7/08	10.9
Koserefski River	6/29	7/18	19	7/09	9.9
Carnation Creek	6/30	7/21	21	7/09	6.6
Paradise Creek	6/24	7/21	27	7/11	12.9
Tuckers Slough	7/01	7/19	18	7/11	9.2
Wood Creek	7/14	7/18	4	7/16	2.8

Table 8.–Average travel rates (km/day) and standard deviations (SD) for summer chum salmon tagged in 2014.

			Release to Paimiut		Paimiut to mouth of tributary		Mouth of tributary to farthest tower		Paimiut to farthest tower	
Stock	Distance (km)	*N*	Average	SD	Average	SD	Average	SD	Average	SD
Bonasila River	120.1	102	15.5	4.9	31.5	11.0	–	–	–	–
Anvik River	187.1	212	16.7	4.1	32.9	8.7	21.0	8.0	28.6	7.5
Innoko River	267.3	2	13.6	4.9	41.3	2.1	–	–	–	–
Nulato River	400.4	37	17.4	4.2	35.8	7.8	–	–	–	–
Lower Koyukuk River	457.1	101	16.6	5.0	48.4	8.2	–	–	–	–
Gisasa River	531.8	11	13.1	2.9	39.9	5.3	29.2	10.3	37.0	6.0
Melozitna River	577.0	21	14.9	4.0	40.7	6.2	–	–	–	–
Tanana River Mainstem	849.7	4	10.9	4.1	36.9	5.8	23.7	3.5	35.9	7.0
Hogotza River	884.4	9	16.1	3.4	53.3	4.6	45.3	11.9	47.7	8.2
Upper Koyukuk River	925.2	62	15.6	4.8	50.7	6.5	49.6	7.8	50.0	6.6
Chena River	1,109.9	3	17.0	2.5	38.9	5.7	31.7	0.5	35.9	2.8
Salcha River	1,174.0	5	9.9	4.7	39.2	3.9	25.1	3.2	33.8	3.0

Note: Rates are shown for travel between the tagging location (Release) and the first tracking station (Paimiut), between Paimiut and the mouth of the fish's spawning tributary, between mouth of the fish's spawning tributary and the farthest tower up the fish's spawning tributary, and between Paimiut and farthest tower. En dashes indicate no data; i.e., fish that were last picked up by the tracking station at the mouth of the spawning tributary.

Table 9.–Average travel times (days) and standard deviations (SD) for summer chum salmon tagged in 2014.

			Release to Paimiut		Paimiut to mouth of tributary		Mouth of tributary to farthest tower		Paimiut to farthest tower	
Stock	Distance (km)	*N*	Average	SD	Average	SD	Average	SD	Average	SD
Bonasila River	120.1	102	1.6	0.8	4.7	3.0	–	–	–	–
Anvik River	187.1	212	1.4	0.5	5.1	1.8	1.9	0.9	7.1	2.9
Innoko River	267.3	2	1.8	0.6	6.5	0.3	–	–	–	–
Nulato River	400.4	37	1.3	0.4	12.1	3.6	–	–	–	–
Lower Koyukuk River	457.1	101	1.4	0.5	10.0	2.6	–	–	–	–
Gisasa River	531.8	11	1.7	0.5	11.8	1.7	3.1	2.0	14.9	2.9
Melozitna River	577.0	21	1.6	0.5	14.8	2.6	–	–	–	–
Tanana River Mainstem	849.7	4	2.3	1.0	23.6	3.6	7.6	1.1	27.4	8.0
Hogotza River	884.4	9	1.4	0.3	8.8	0.8	10.5	4.7	19.3	4.6
Upper Koyukuk River	925.2	62	1.6	0.7	9.3	1.3	9.7	2.1	19.0	2.9
Chena River	1,109.9	3	1.3	0.2	22.3	3.4	8.2	0.1	31.2	2.6
Salcha River	1,174.0	5	2.6	0.9	22.0	2.1	13.1	1.7	35.1	2.9

Note: Average number of days are shown for travel between the tagging location (Release) and the first tracking station (Paimiut), between Paimiut and the mouth of the fish's spawning tributary, between mouth of the fish's spawning tributary and the farthest tower up the fish's spawning tributary, and between Paimiut and farthest tower. En dashes indicate no data; i.e., fish that were last picked up by the tracking station at the mouth of the spawning tributary.

Table 10.–Average travel rates (km/day) and standard deviations (SD) for summer chum salmon migrating to lower, upper Koyukuk, and Tanana river regions of the Yukon River in 2014.

	Within mainstem Yukon River			Off mainstem Yukon River		
Region	*N*	Average	SD	*N*	Average	SD
Lower	378	33.4	9.4	208	21.4	8.3
Upper Koyukuk River	66	51.0	6.4	66	49.0	8.4
Tanana River	12	38.4	4.7	9	26.2	4.1

Table 11.–Average travel rates (km/day) and standard deviations (SD) for summer chum salmon tagged in 2015.

			Release to Paimiut		Paimiut to mouth of tributary		Mouth of tributary to farthest tower		Paimiut to farthest tower	
Stock	Distance (km)	*N*	Average	SD	Average	SD	Average	SD	Average	SD
Bonasila River	120.1	104	18.2	6.7	40.9	9.7	–	–	–	–
Anvik River	187.1	190	19.0	4.7	34.8	8.3	16.0	7.8	27.7	7.4
Innoko River	267.3	10	21.8	4.1	36.1	6.9	–	–	–	–
Nulato River	400.4	2	18.0	4.9	42.3	2.9	–	–	–	–
Lower Koyukuk River	457.1	158	19.2	4.4	50.2	7.3	–	–	–	–
Gisasa River	531.8	20	20.0	4.6	46.0	7.6	27.8	17.2	37.3	12.1
Melozitna River	577.0	24	21.6	4.3	43.0	9.0	–	–	–	–
Tanana River Mainstem	849.7	19	13.9	5.6	34.5	8.9	35.7	3.0	31.9	8.6
Hogotza River	884.4	32	22.5	3.4	54.8	5.8	59.7	8.1	56.8	6.2
Upper Koyukuk River	925.2	67	20.2	4.8	54.2	6.3	62.3	7.4	57.6	6.5
Chena River	1,109.9	1	16.1	–	38.4	–	26.0	–	34.5	–
Salcha River	1,174.0	3	12.7	1.4	40.3	0.2	14.3	0.8	32.9	0.5

Note: Rates are shown for travel between the tagging location (Release) and the first tracking station (Paimiut), between Paimiut and the mouth of the fish's spawning tributary, between mouth of the fish's spawning tributary and the farthest tower up the fish's spawning tributary, and between Paimiut and farthest tower. En dashes indicate no data; i.e., fish that were last picked up by the tracking station at the mouth of the spawning tributary.

Table 12.–Average travel times (days) and standard deviations (SD) for summer chum salmon tagged in 2015.

Stock	Distance (km)	*N*	Release to Paimiut		Paimiut to mouth of tributary		Mouth of tributary to farthest tower		Paimiut to farthest tower	
			Average	SD	Average	SD	Average	SD	Average	SD
Bonasila River	120.1	104	1.7	2.9	3.2	1.2	–	–	–	–
Anvik River	187.1	190	1.3	0.6	4.7	1.3	2.8	2.5	7.3	2.8
Innoko River	267.3	10	1.0	0.2	7.7	1.6	–	–	–	–
Nulato River	400.4	2	1.3	0.4	9.7	0.6	–	–	–	–
Lower Koyukuk River	457.1	158	1.2	0.4	9.4	1.6	–	–	–	–
Gisasa River	531.8	20	1.2	0.3	10.3	1.6	6.6	9.1	17.2	9.5
Melozitna River	577.0	24	1.1	0.3	14.6	5.4	–	–	–	–
Tanana River Mainstem	849.7	19	2.1	2.0	26.6	7.9	5.0	0.4	31.1	9.3
Hogotza River	884.4	32	1.0	0.1	8.5	0.9	7.3	1.4	15.9	2.0
Upper Koyukuk River	925.2	67	1.1	0.3	8.7	1.1	7.8	3.0	16.5	3.3
Chena River	1,109.9	1	1.4	–	22.3	–	10.0	–	32.3	–
Salcha River	1,174.0	3	1.7	0.2	25.6	0.1	10.3	0.6	35.9	0.6

Note: Average number of days are shown for travel between the tagging location (Release) and the first tracking station (Paimiut), between Paimiut and the mouth of the fish's spawning tributary, between mouth of the fish's spawning tributary and the farthest tower up the fish's spawning tributary, and between Paimiut and farthest tower. En dashes indicate no data; i.e., fish that were last picked up by the tracking station at the mouth of the spawning tributary.

Table 13.–Average travel rates (km/day) and standard deviations (SD) for summer chum salmon migrating to lower, upper Koyukuk, and Tanana river regions of the Yukon River in 2015.

Region	Within mainstem Yukon River			Off mainstem Yukon River		
	N	Average	SD	*N*	Average	SD
Lower	343	37.9	9.4	194	17.3	9.9
Upper Koyukuk River	98	54.4	6.2	98	61.7	7.4
Tanana River	14	36.0	7.8	6	23.4	10.6

Table 14.–Mean travel rates (km/day) and standard deviations (SD) for radiotagged summer chum salmon traveling through the mainstem Yukon River during tagging strata in 2014.

Stratum	Dates	*N*	Mean	SD
1	6/12–6/17	57	40.9	12.1
2	6/18–6/24	173	42.8	11.9
3	6/25–6/30	182	35.4	10.2
4	7/1–7/5	77	34.7	11.7
5	7/6–7/13	68	36.8	8.2

Table 15.–Mean travel rates (km/day) and standard deviations (SD) for radiotagged summer chum salmon traveling through the mainstem Yukon River during tagging strata in 2015.

Stratum	Dates	*N*	Mean	SD
1	6/12–6/18	52	46.8	10.9
2	6/19–6/27	188	45.2	11.3
3	6/28–7/5	240	44.1	10.9
4	7/6–7/12	87	39.3	8.6
5	7/13–7/21	44	39.8	10.7

Table 16.–Proportions and standard deviations (SD) of tagged summer chum salmon that entered various tributaries or non-terminal areas within the Yukon River drainage in 2014.

	Description	Proportion	SD
Terminal areas			
	Anvik River	0.208	0.013
	Bear Creek	0.026	0.005
	Big Salt River	0.001	0.001
	Blackburn Creek	0.006	0.003
	Bonasila River	0.113	0.010
	Dugan Creek	0.001	0.001
	Grayling Creek	0.003	0.002
	Illinois Creek	0.001	0.001
	Innoko River	0.002	0.001
	Kaltag River	0.012	0.003
	Khotol River	0.001	0.001
	Koserefski River	0.002	0.001
	Koyukuk River	0.220	0.013
	Melozitna River	0.020	0.004
	Ninemile River	0.002	0.002
	Nulato River	0.032	0.006
	Rodo River	0.034	0.006
	Shovel Creek	0.001	0.001
	Simon Creek	0.002	0.002
	Stink Creek	0.030	0.005
	Tanana River	0.013	0.004
	Thompson Creek	0.046	0.007
	Tozitna River	0.010	0.003
	Ukawutni Creek	0.001	0.001
	Unnamed	0.004	0.002
	Yuki River	0.007	0.003
Non-terminal areas			
	Between Paimiut and the Koyukuk River	0.178	0.012
	Between the Koyukuk and Tanana rivers	0.018	0.004
	Above the Tanana River	0.006	0.003

Note: Non-terminal areas include tagged fish that remained on, or in close proximity to, the Yukon River mainstem.

Table 17.–Proportions and standard deviations (SD) of tagged summer chum salmon that entered various tributaries or non-terminal areas within the Yukon River drainage in 2015.

Description		Proportion	SD
Terminal areas			
	Anvik River	0.213	0.013
	Bear Creek	0.016	0.004
	Big Salt River	0.002	0.001
	Blackburn Creek	0.008	0.003
	Bonanza Creek	0.001	0.001
	Bonasila River	0.091	0.009
	Dugan Creek	0.003	0.002
	Grayling Creek	0.003	0.002
	Innoko River	0.014	0.004
	Kaltag River	0.007	0.002
	Khotol River	0.002	0.001
	Koserefski River	0.003	0.002
	Koyukuk River	0.268	0.014
	Melozitna River	0.023	0.005
	Minook Creek	0.002	0.001
	Ninemile River	0.011	0.003
	North Creek	0.001	0.001
	Nulato River	0.043	0.006
	Paradise Creek	0.003	0.002
	Rodo River	0.036	0.006
	Simon Creek	0.006	0.002
	Stink Creek	0.023	0.005
	Tanana River	0.010	0.003
	Thompson Creek	0.039	0.006
	Tozitna River	0.018	0.004
	Ukawutni Creek	0.003	0.002
	Wood Creek	0.003	0.002
Non-terminal areas			
	Between Paimiut and the Koyukuk River	0.117	0.010
	Between the Koyukuk and Tanana rivers	0.030	0.005
	Above the Tanana River	0.004	0.002

Note: Non-terminal areas include tagged fish that remained on, or in close proximity to, the Yukon River mainstem.

Table 18.–Recoveries of tagged summer chum salmon at escapement monitoring projects in 2014 and 2015.

			2014			2015		
Km from Yukon River Mouth	Project location	Project type	Number recaptured[a]	Number examined	Marked fraction (%)	Number recaptured[a]	Number examined	Marked fraction (%)
512	Anvik River	Sonar	204	399,796	0.051	184	374,968	0.049
912	Gisasa River	Weir	8	32,523[b]	–	22	42,747	0.051
1,570	Henshaw Creek	Weir	–	–	–	20	238,529	0.008
1,481	Chena River	Tower	3	13,303[b]	–	1	8,620[b]	-
1,553	Salcha River	Tower	4	–	–	3	12,812[b]	-
	Total		219	445622		230	677,676	
Totals for mark–recapture estimate			204	399,796	0.051	206	417,715	0.049

Note: En dashes indicate that the project or survey did not operate or there was inadequate escapement information to calculate a marked fraction. Boxes indicate that the numbers were used for the pooled Chapman's modified Petersen estimates.

[a] Number of radiotagged fish recorded in river by tracking stations or aerial tracking.

[b] Incomplete summer chum salmon passage estimate.

Table 19.–Drainagewide summer chum salmon run estimates for the Yukon River in 2014 and 2015.

	2014	2015
Andreafsky River escapement	75,586	97,618
Commercial harvest below Paimiut Station	427,347	354,086
Subsistence harvest below Paimiut Station	53,209	49,051
Abundance estimate above Paimiut Station	2,110,147	2,120,866
Total run	2,663,265	2,604,688

Note: Escapement into the Andreafsky River is estimated by doubling the passage at the East Fork Andreafsky River weir.

Table 20.–Summary of the accepted changes to the anadromous waters catalog (AWC) that resulted from summer chum salmon radiotagging and tracking in 2014.

Name	AWC Region	AWC Number	Result	Activity Code
Huslia River	Kateel River D-2	334-40-11000-2125-3171	Adding life phase (spawning)	Spawning
Billy Hawk Creek	Shungnak A-2	334-40-11000-2125-3171-4351	Adding life phase (spawning)	Spawning
Billy Hawk Creek	Shungnak A-3	334-40-11000-2125-3171-4351	Adding life phase (spawning)	Spawning
Billy Hawk Creek	Kateel River D-2	334-40-11000-2125-3171-4351	Adding life phase (spawning)	Spawning
Billy Hawk Creek	Shungnak A-2	334-40-11000-2125-3171-4351-5030	Adding new stream	Spawning/Present
Billy Hawk Creek	Shungnak A-3	334-40-11000-2125-3171-4351-5045	Adding new stream	Spawning/Present
Billy Hawk Creek	Shungnak A-3	334-40-11000-2125-3171-4351-5045	Adding new stream	Present
Billy Hawk Creek	Shungnak A-4	334-40-11000-2125-3171-4351-5045	Adding new stream	Present
Hughes Creek	Hughes A-3	334-40-11000-2125-3555	Adding new stream	Spawning/Present
Siruk Creek	Hughes C-1	334-40-11000-2125-3661-4035	Adding new stream	Spawning
Unnamed	Ruby D-3	334-40-11000-2311	Adding new stream	Spawning/Present
Unnamed	Melozitna A-3	334-40-11000-2311	Adding new stream	Spawning/Present
Woodyard Creek	Kateel River A-4	334-40-11000-2125-3025	Adding new stream	Spawning/Present
Grayling Creek	Holy Cross D-3	334-30-11000-2781-3011	Adding new stream	Spawning
Papa Willik Creek	Unalakleet B-1	334-30-11000-2960	Adding new stream	Present
Shovel Creek	Unalakleet B-1	334-30-11000-2960-3016	Adding new stream	Spawning/Present
Unnamed	Russian Mission D-6	334-30-11000-2301-3007	Adding new stream	Spawning
Unnamed	Russian Mission D-6	334-30-11000-2261	Adding new stream	Spawning
Yuki River	Nulato C-1	334-40-11000-2230	Adding new species to stream	Present
Yuki River	Nulato B-1	334-40-11000-2230	Adding new species to stream	Present
Yuki River	Nulato C-2	334-40-11000-2230	Adding new species to stream	Present
Yuki River	Nulato A-2	334-40-11000-2230	Adding new species to stream	Present
Yuki River	Ruby C-6	334-40-11000-2230	Adding new species to stream	Present

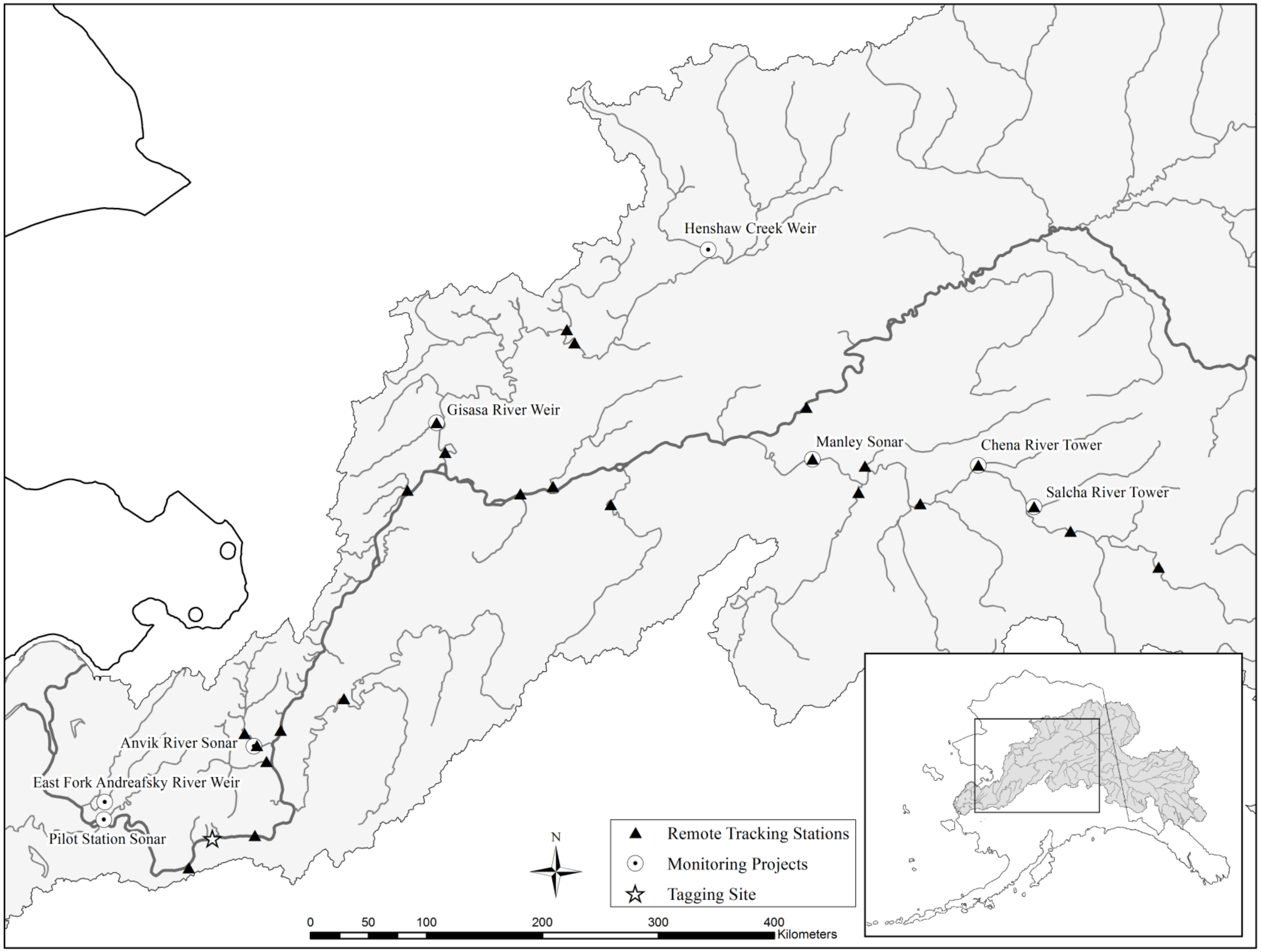


Figure 1.–Yukon River drainage showing summer chum salmon monitoring projects, the tagging site, and the remote tracking stations used during 2014 and 2015.

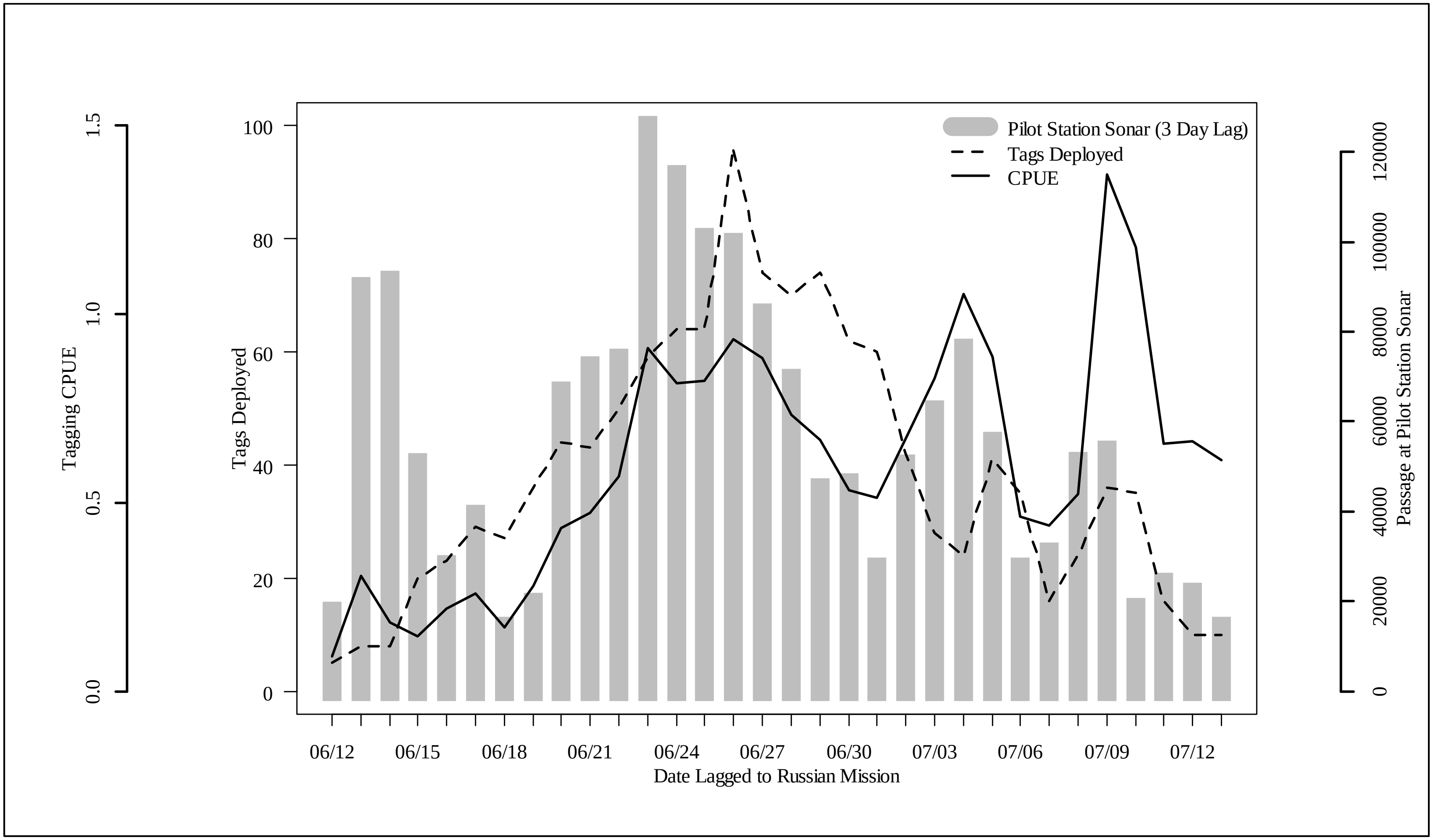


Figure 2.–Daily tag deployment, number of fish caught per fathom hour of fishing (CPUE), and summer chum salmon passage at the Pilot Station sonar in 2014.

Note: It takes summer chum salmon about 3 days to travel from the Pilot Station sonar to the tagging site near Russian Mission; thus, passage estimates are lagged forward 3 days for comparison with tagging data.

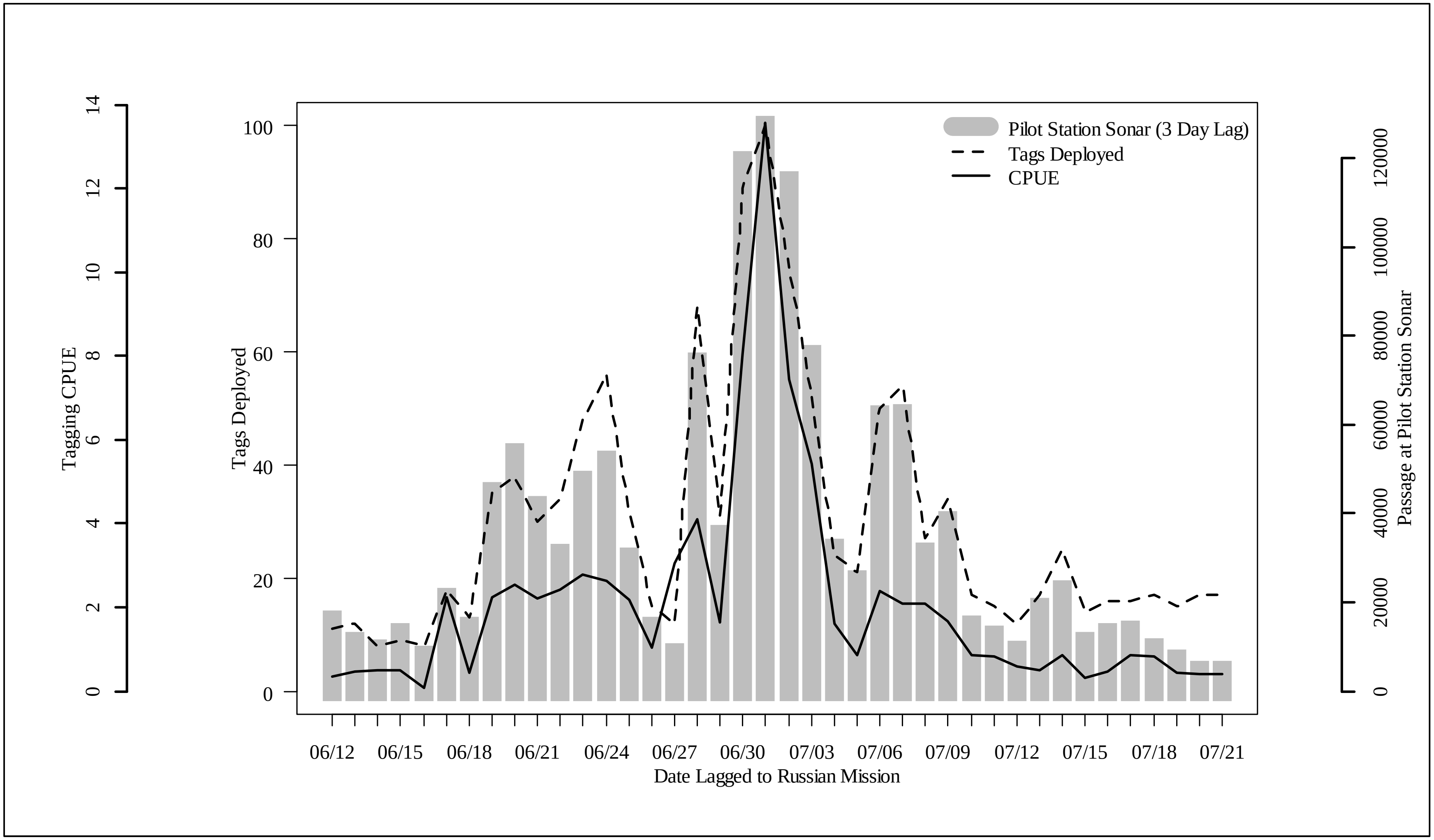


Figure 3.–Daily tag deployment, number of fish caught per fathom hour of fishing (CPUE), and summer chum salmon passage at the Pilot Station sonar in 2015.

Note: It takes summer chum salmon about 3 days to travel from the Pilot Station sonar to the tagging site near Russian Mission; thus, passage estimates are lagged forward 3 days for comparison with tagging data.

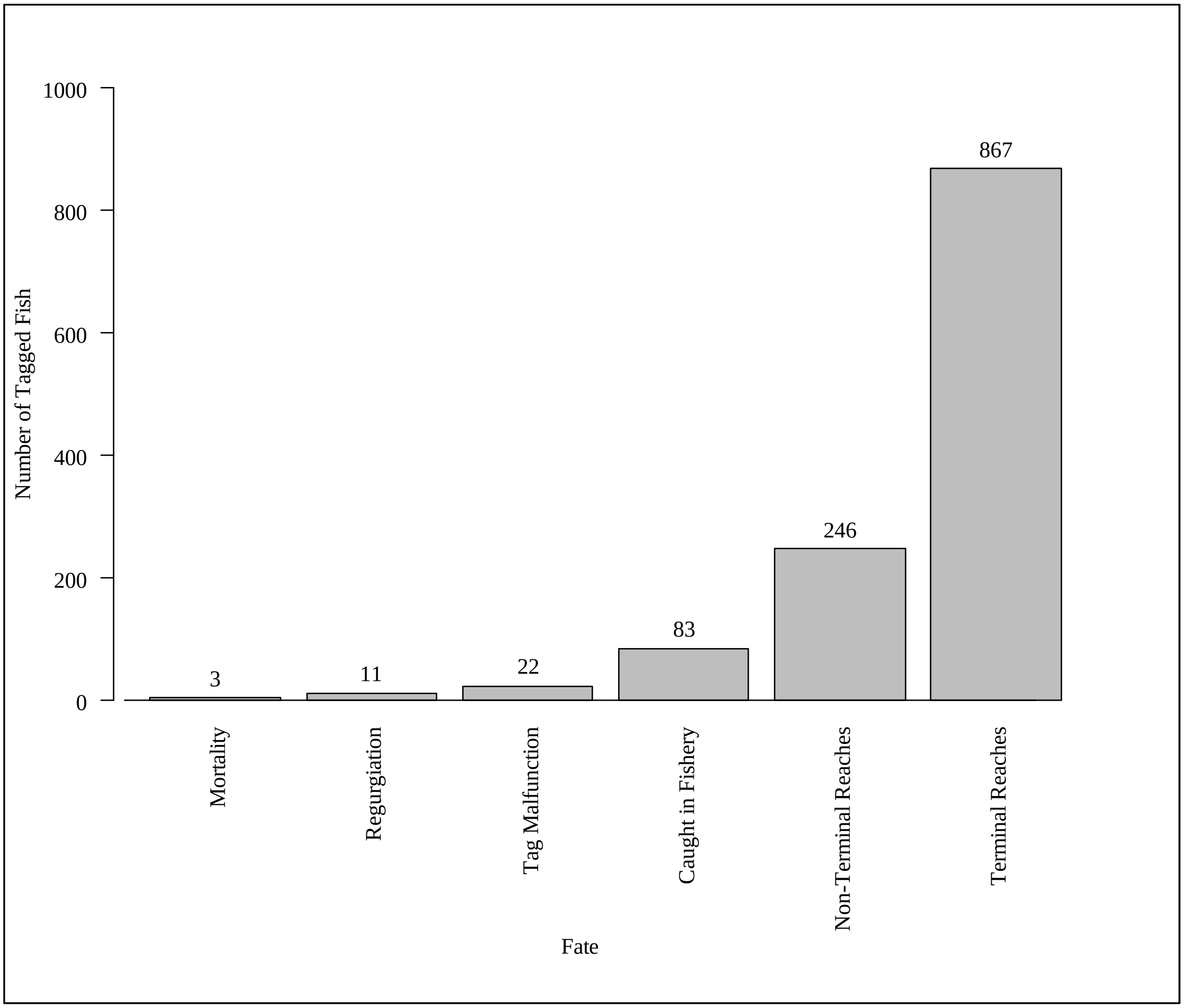


Figure 4.–Number of tagged summer chum salmon with the following fates: mortality due to tagging and handling, regurgitated their tags, had tag malfunction, were caught in the fishery, or traveled to terminal and non-terminal reaches of the Yukon River drainage above Paimiut Station in 2014.

Note: Total numbers of tagged summer chum salmon assigned to each fate are located above the bars.

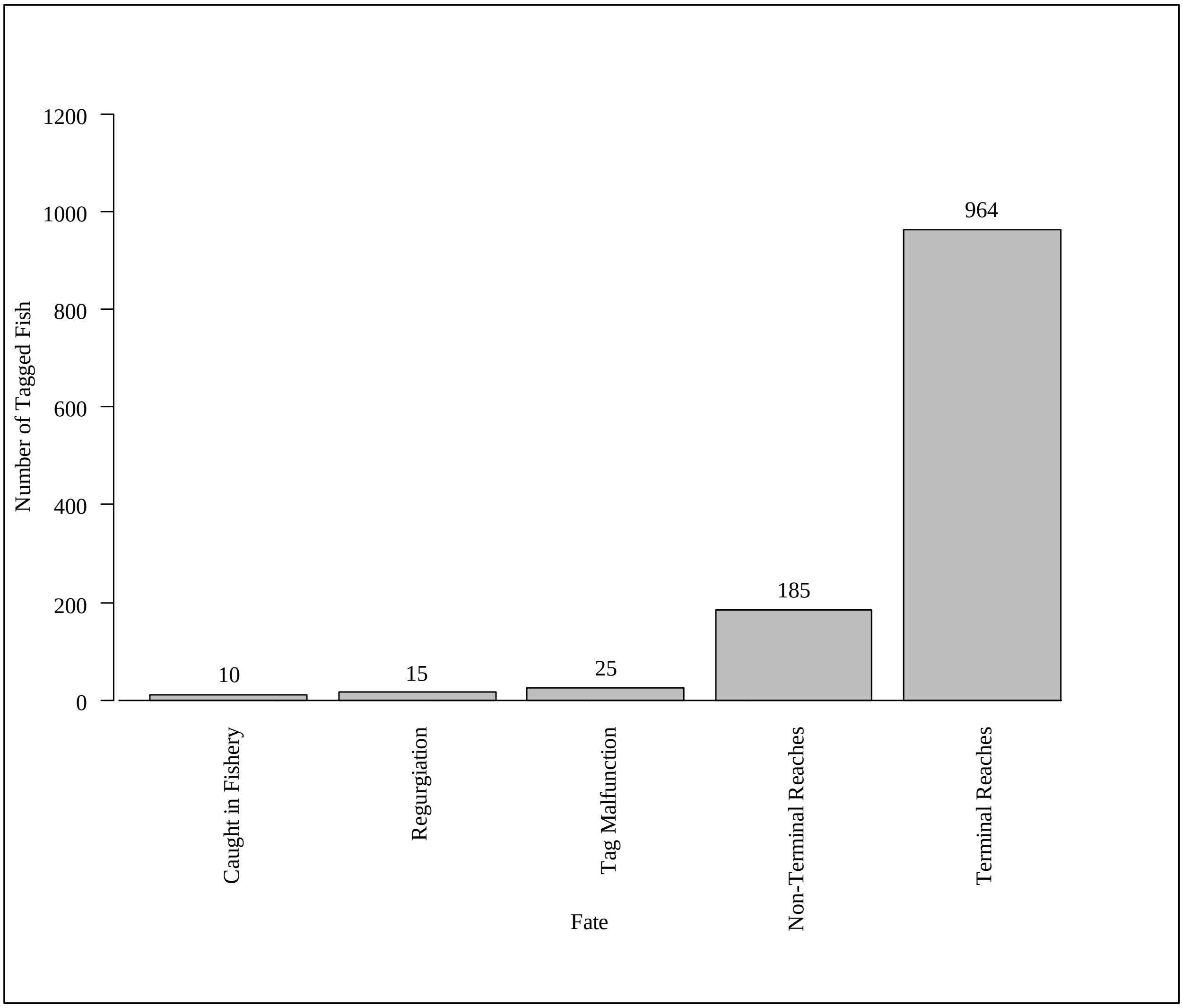


Figure 5.–Number of tagged summer chum salmon with the following fates: caught in the fishery, regurgitated their tags, had tag malfunction, remained below Paimiut Station, or traveled to terminal and non-terminal reaches of the Yukon River drainage above Paimiut Station in 2015.

Note: Total numbers of tagged summer chum salmon assigned to each fate are located above the bars.

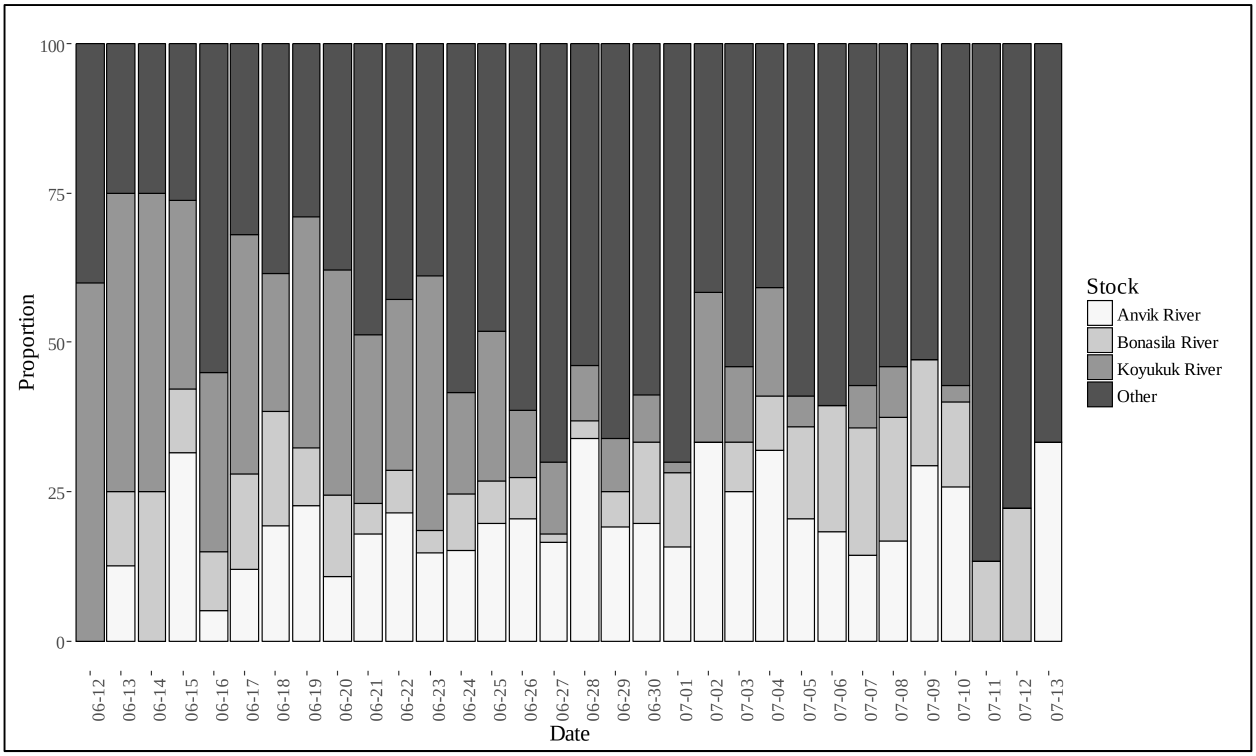


Figure 6.–Relative proportion of summer chum salmon returning to the Anvik, Bonasila, Koyukuk, or other rivers encountered at the tagging site near Russian Mission in 2014.

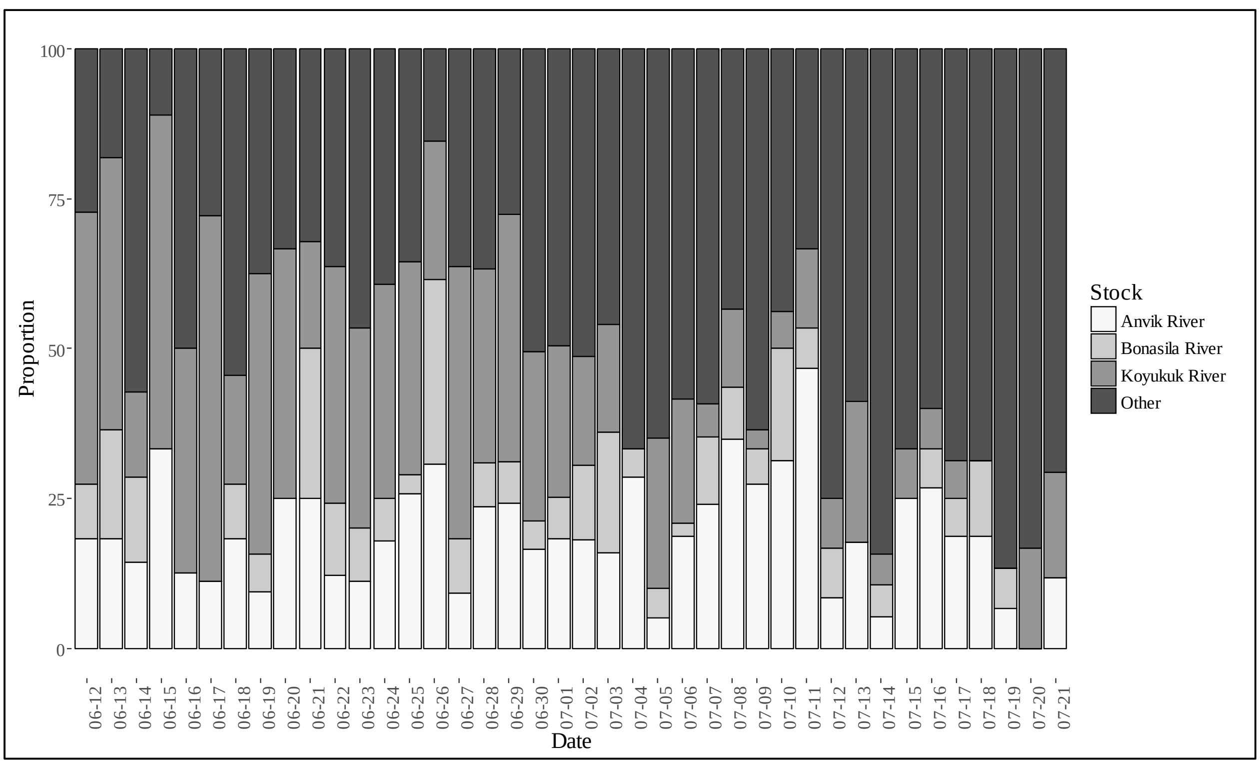


Figure 7.–Relative proportion of summer chum salmon returning to the Anvik, Bonasila, Koyukuk, or other rivers encountered at the tagging site near Russian Mission in 2015.

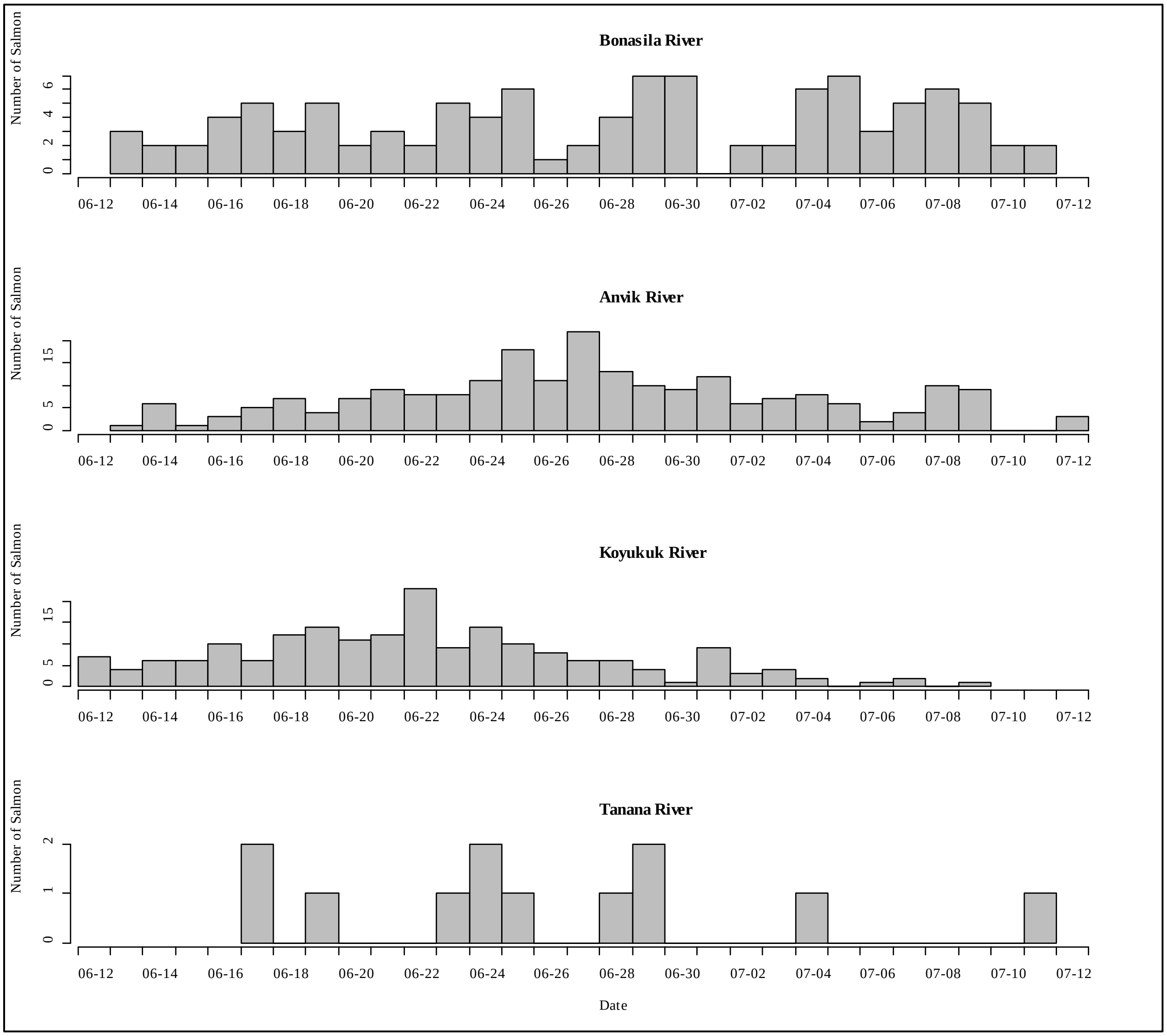


Figure 8.–Total number of Tanana, Bonasila, Koyukuk, and Anvik river fish that were tagged near Russian Mission each day in 2014.

Note: The figures have different *y*-axis scales.

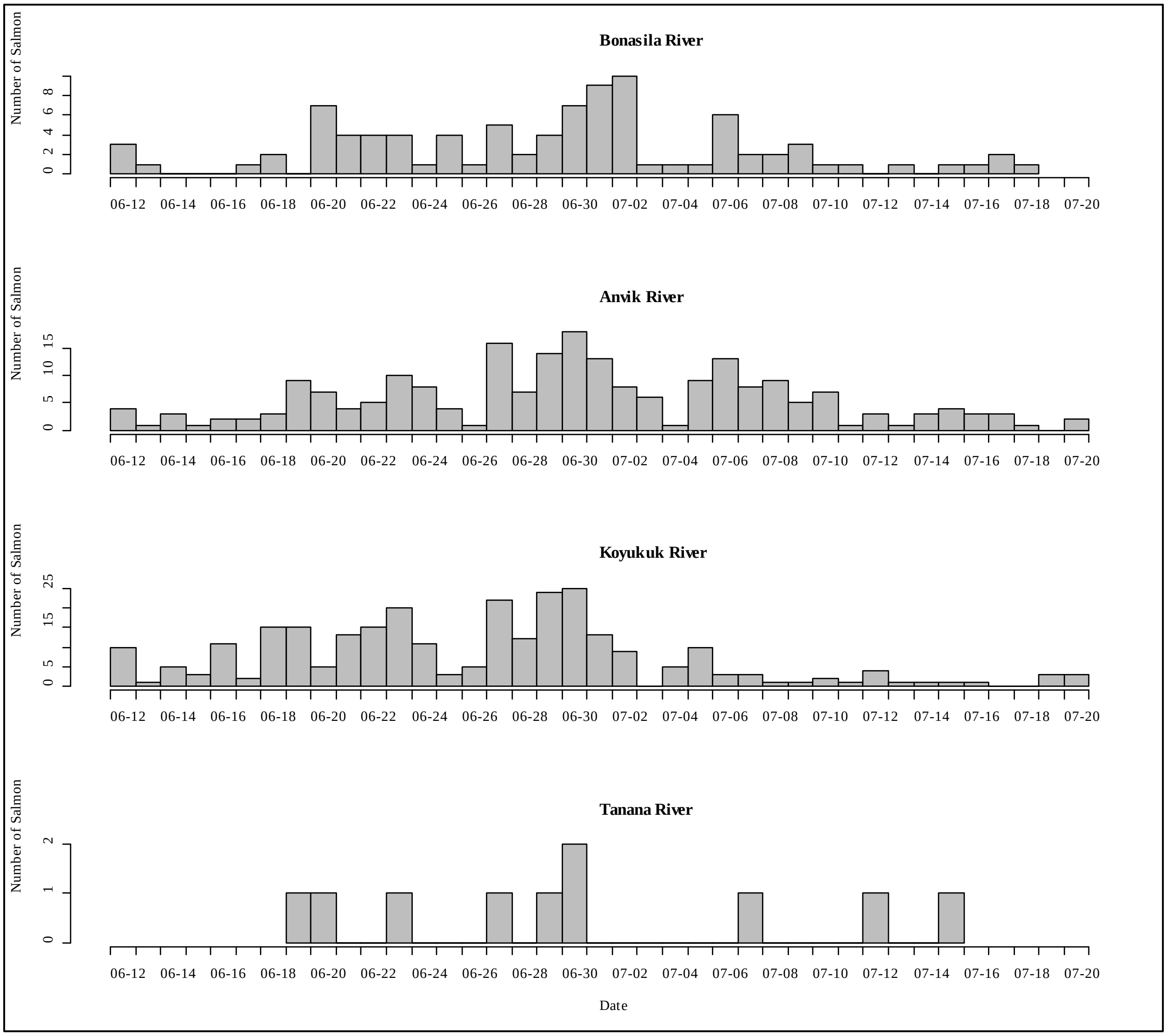


Figure 9.–Total number of Tanana, Bonasila, Koyukuk, and Anvik river fish that were tagged near Russian Mission each day in 2015.

Note: The figures have different *y*-axis scales.

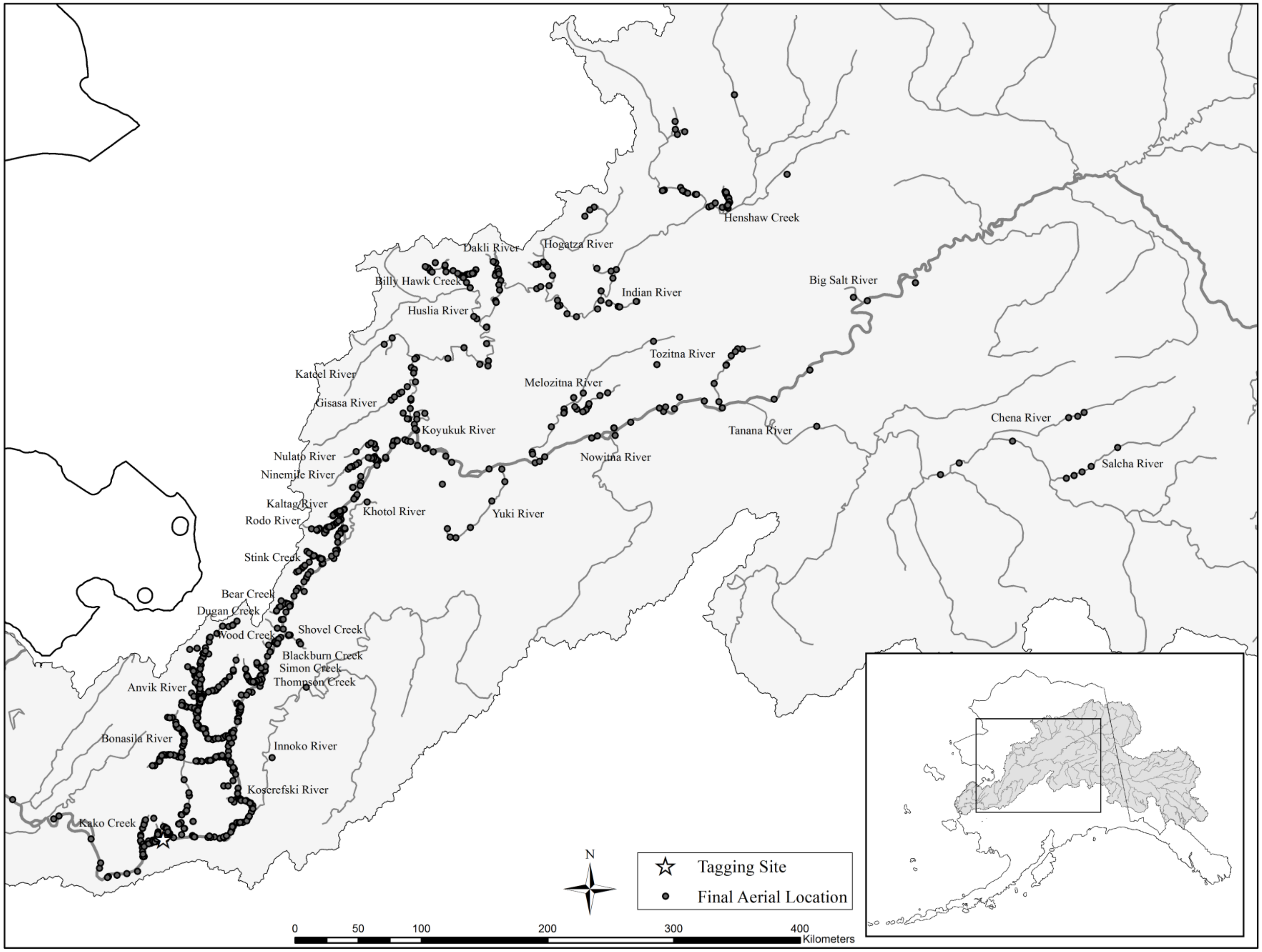


Figure 10.–Yukon River drainage showing the last known location of tagged summer chum salmon during 2014.

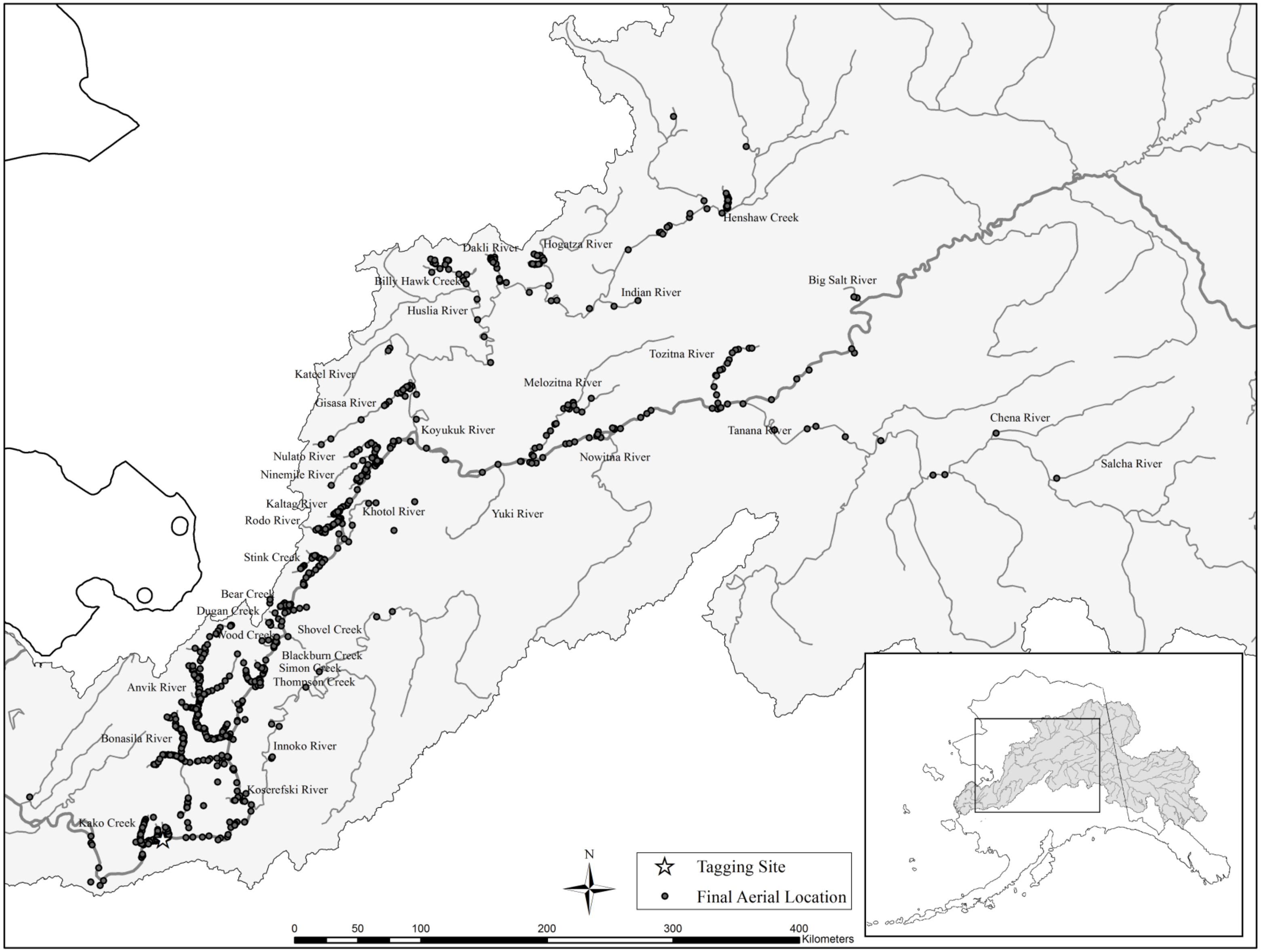


Figure 11.–Yukon River drainage showing the last known location of tagged summer chum salmon during 2015.

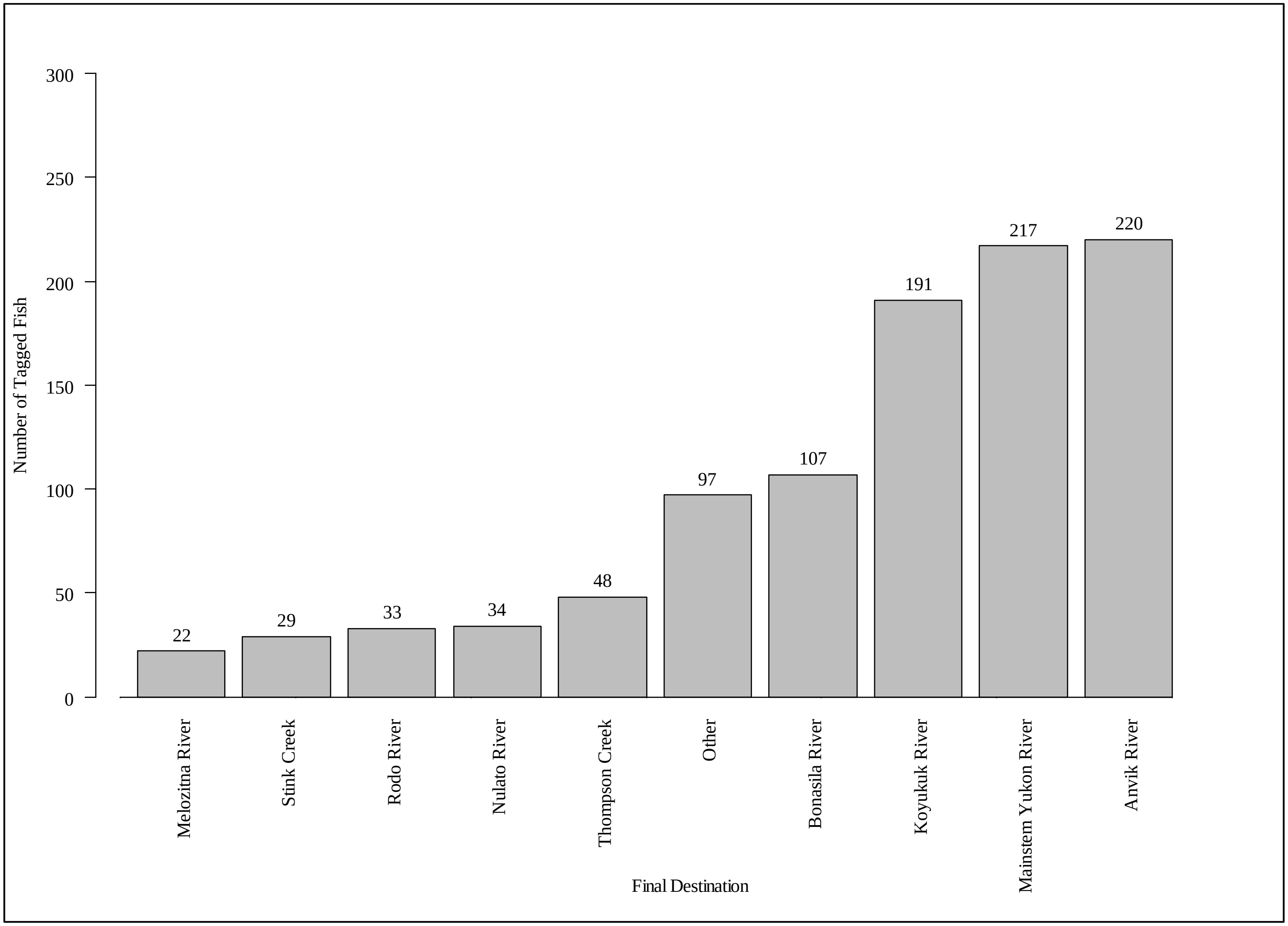


Figure 12.–Number of tagged summer chum salmon that migrated upriver past Paimiut Station and entered various tributaries in 2014.

Note: Tagged salmon in the "Other" category were observed in tributaries that, individually, represented a relatively small component of the summer chum salmon run in 2014. Values shown have not been weighted. Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

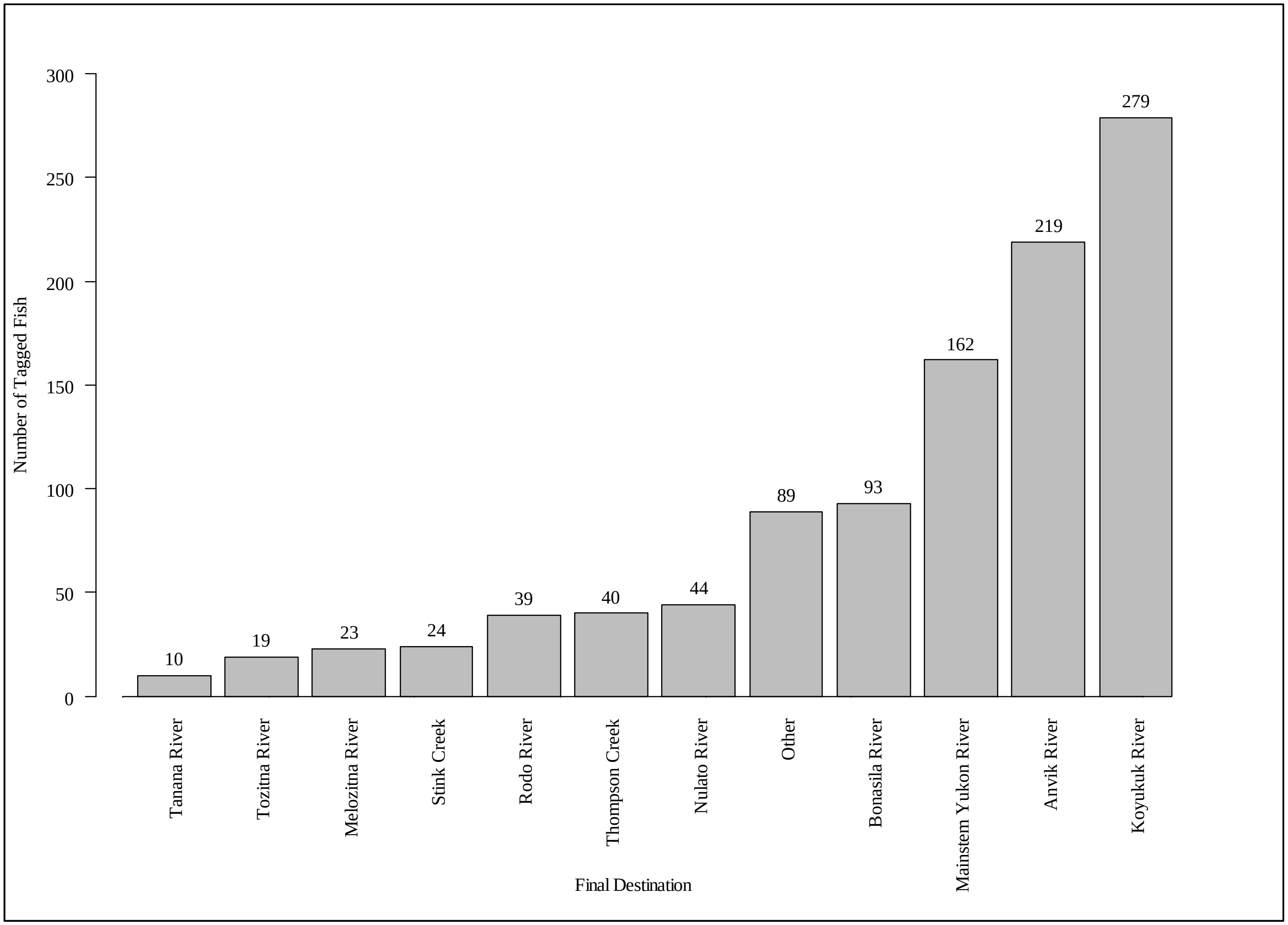


Figure 13.–Number of tagged summer chum salmon that migrated upriver past Paimiut Station and entered various tributaries in 2015.

Note: Tagged salmon in the “Other” category were observed in tributaries that, individually, represented a relatively small component of the summer chum salmon run in 2014. Values shown have not been weighted. Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

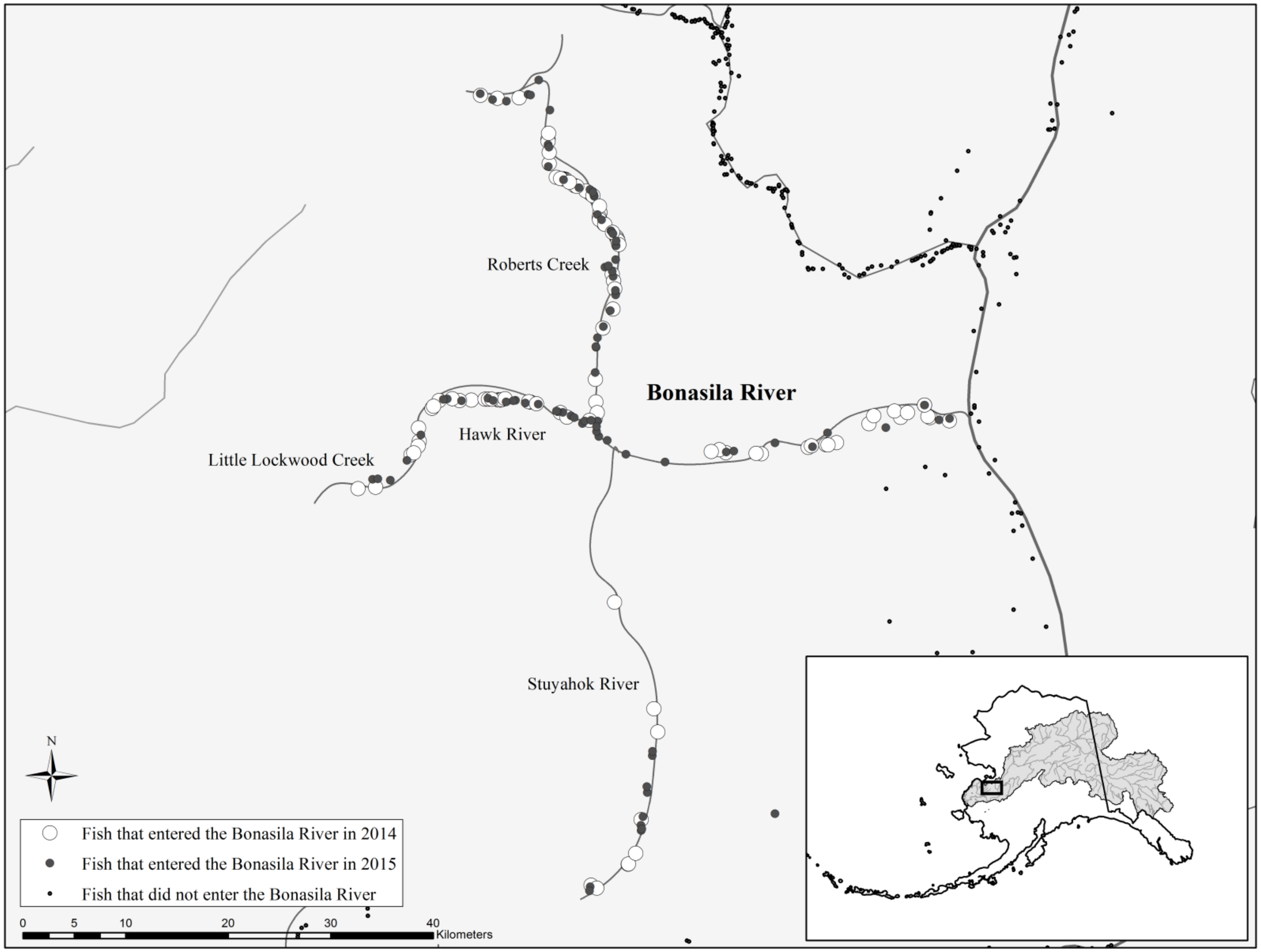


Figure 14.–Final locations of tagged summer chum salmon within the Bonasila River drainage in 2014 and 2015.

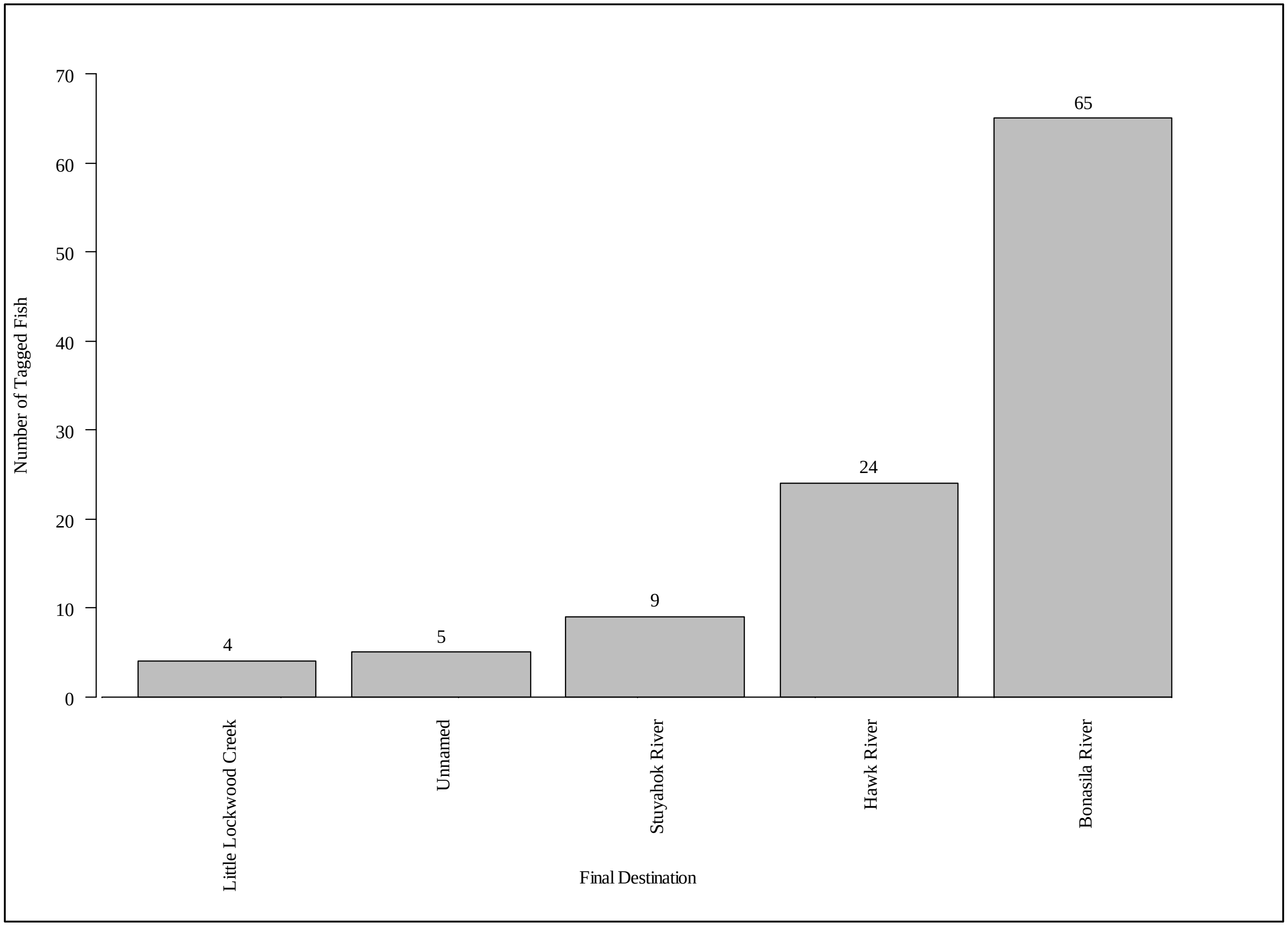


Figure 15.–Number of tagged summer chum salmon that entered tributaries within the Bonasila River drainage or remained on the mainstem Bonasila River in 2014.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

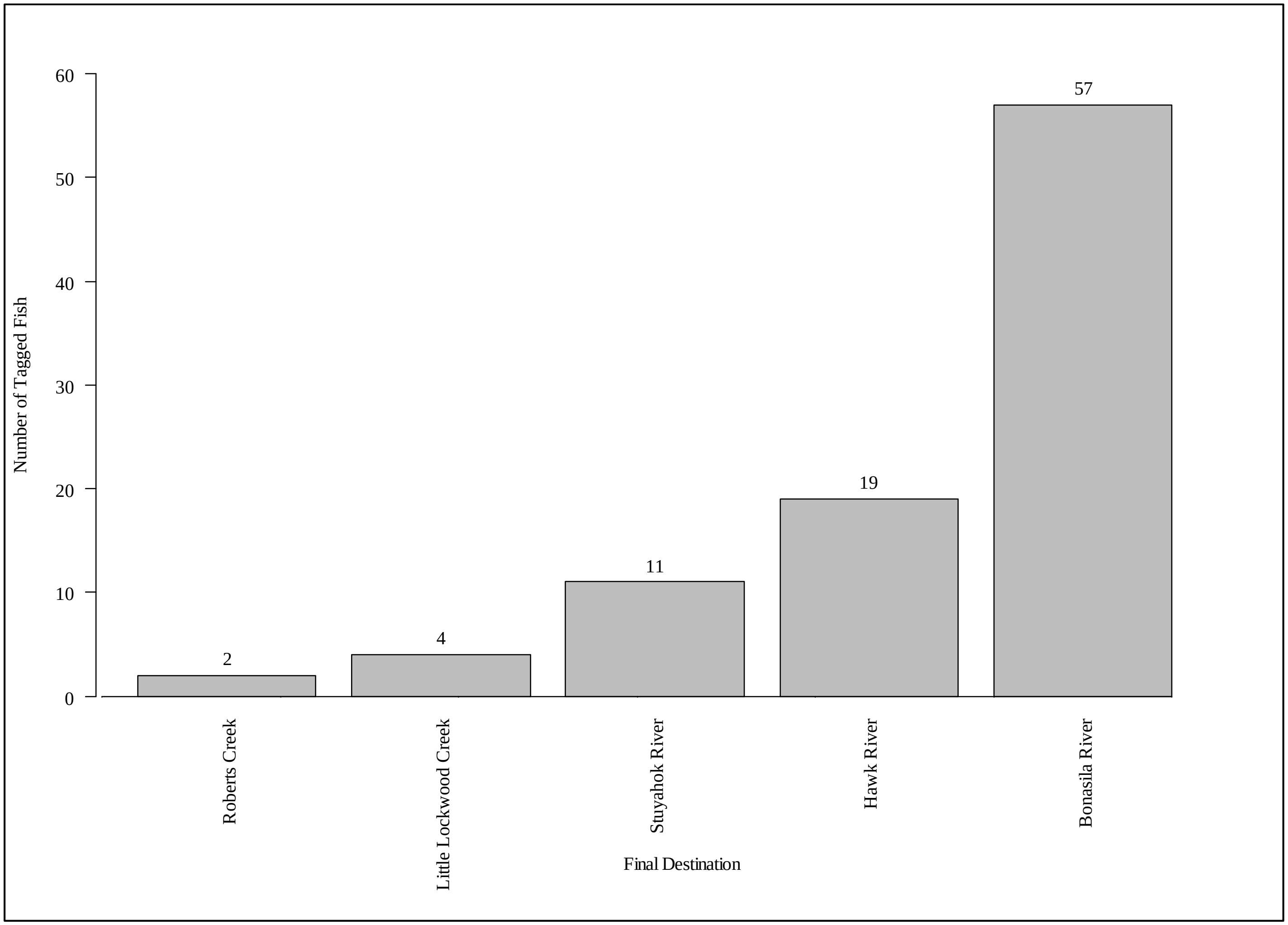


Figure 16.–Number of tagged summer chum salmon that entered tributaries within the Bonasila River drainage or remained on the mainstem Bonasila River in 2015.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

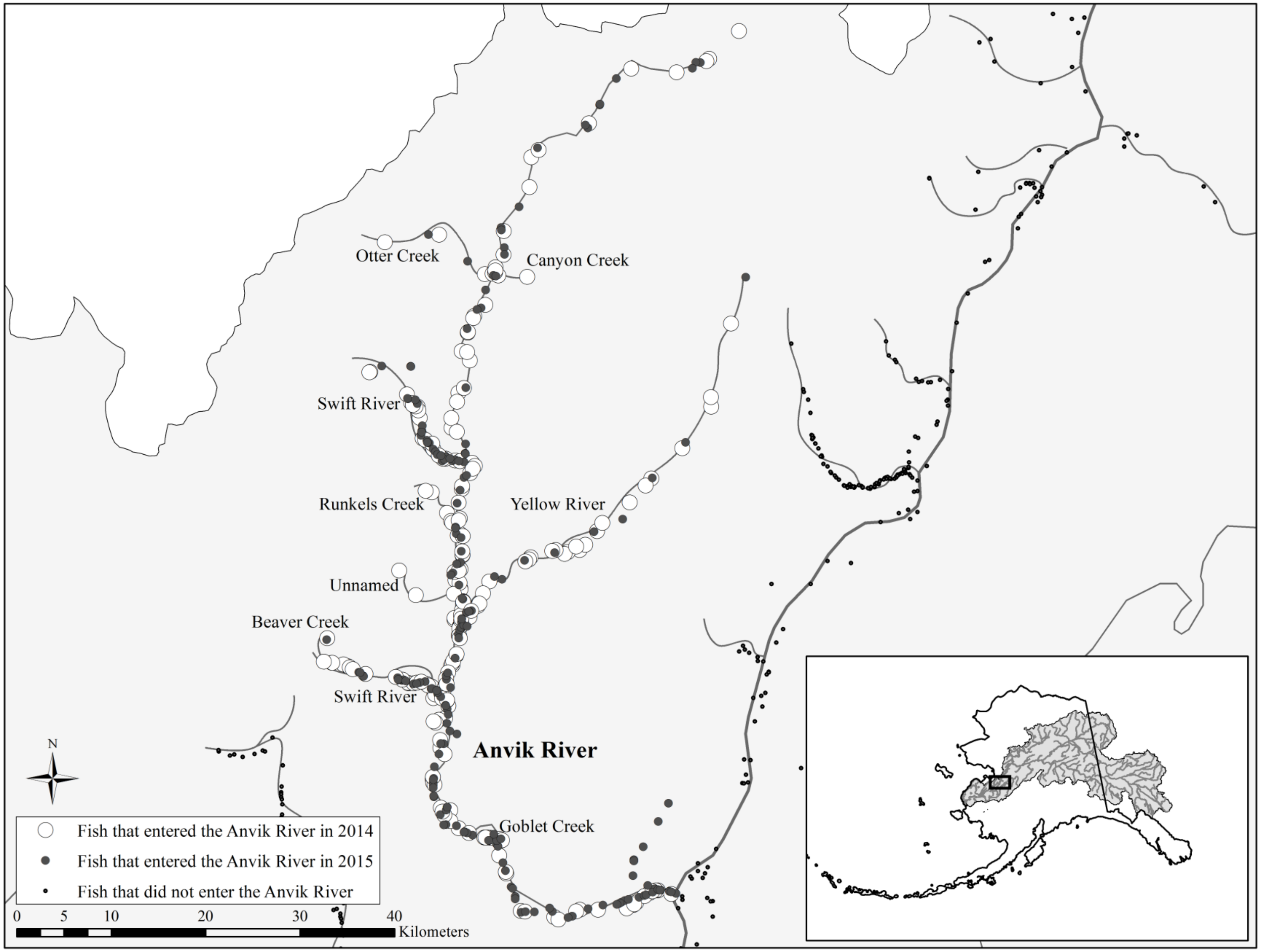


Figure 17.–Final locations of tagged summer chum salmon within the Anvik River drainage in 2014 and 2015.

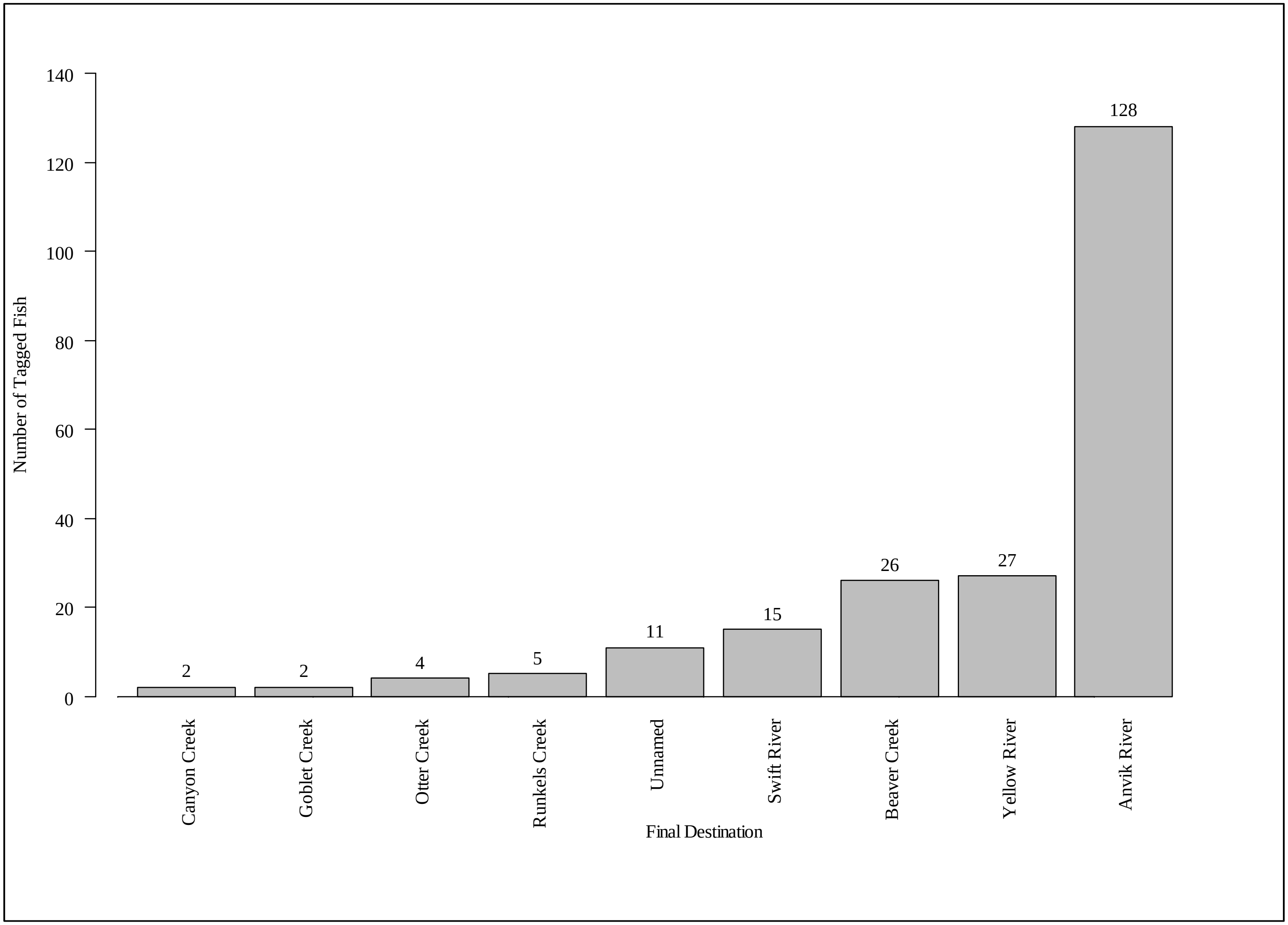


Figure 18.–Number of tagged summer chum salmon that entered tributaries within the Anvik River drainage or remained on the mainstem Anvik River in 2014.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

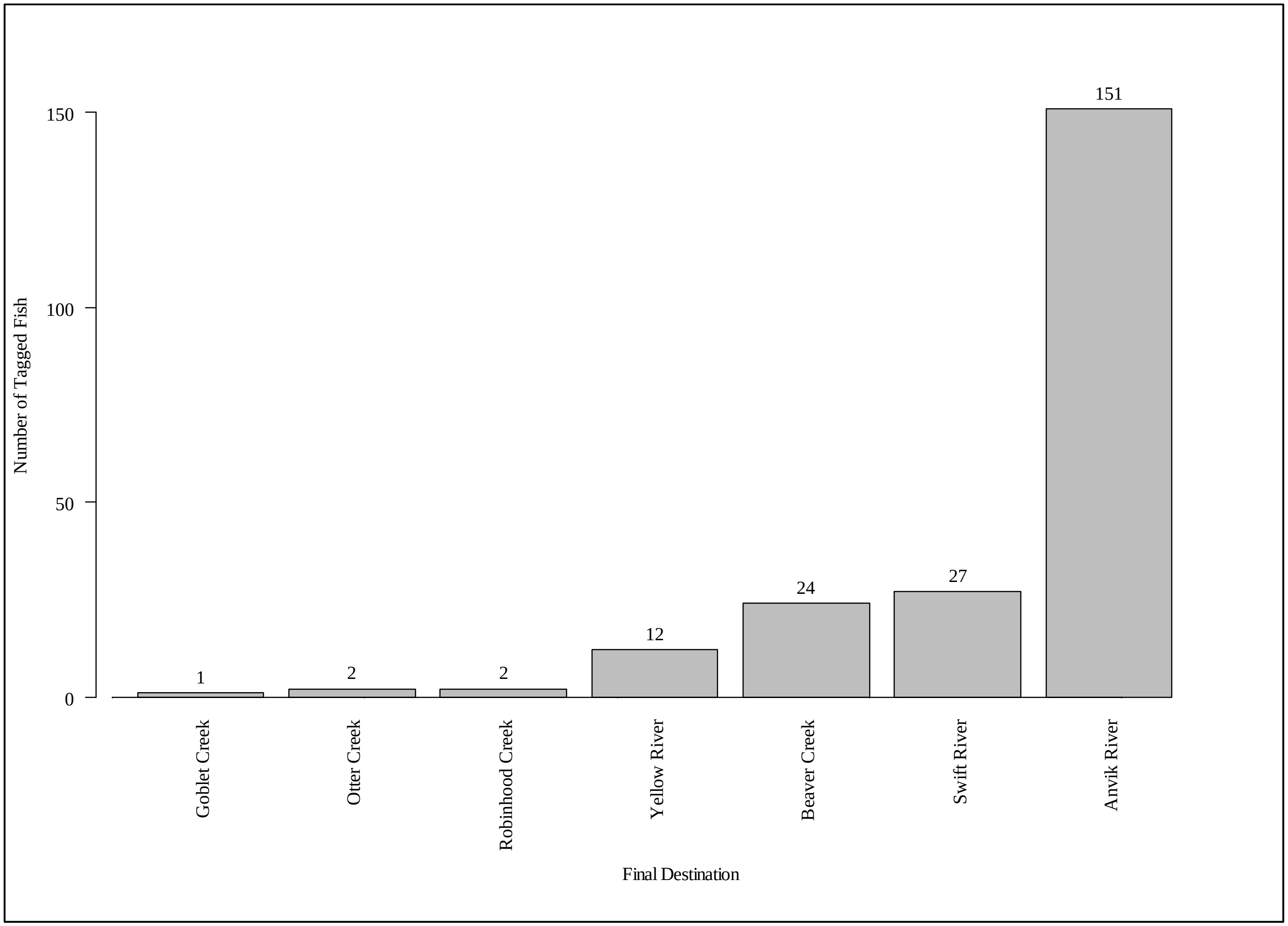


Figure 19.–Number of tagged summer chum salmon that entered tributaries within the Anvik River drainage or remained on the mainstem Anvik River in 2015.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

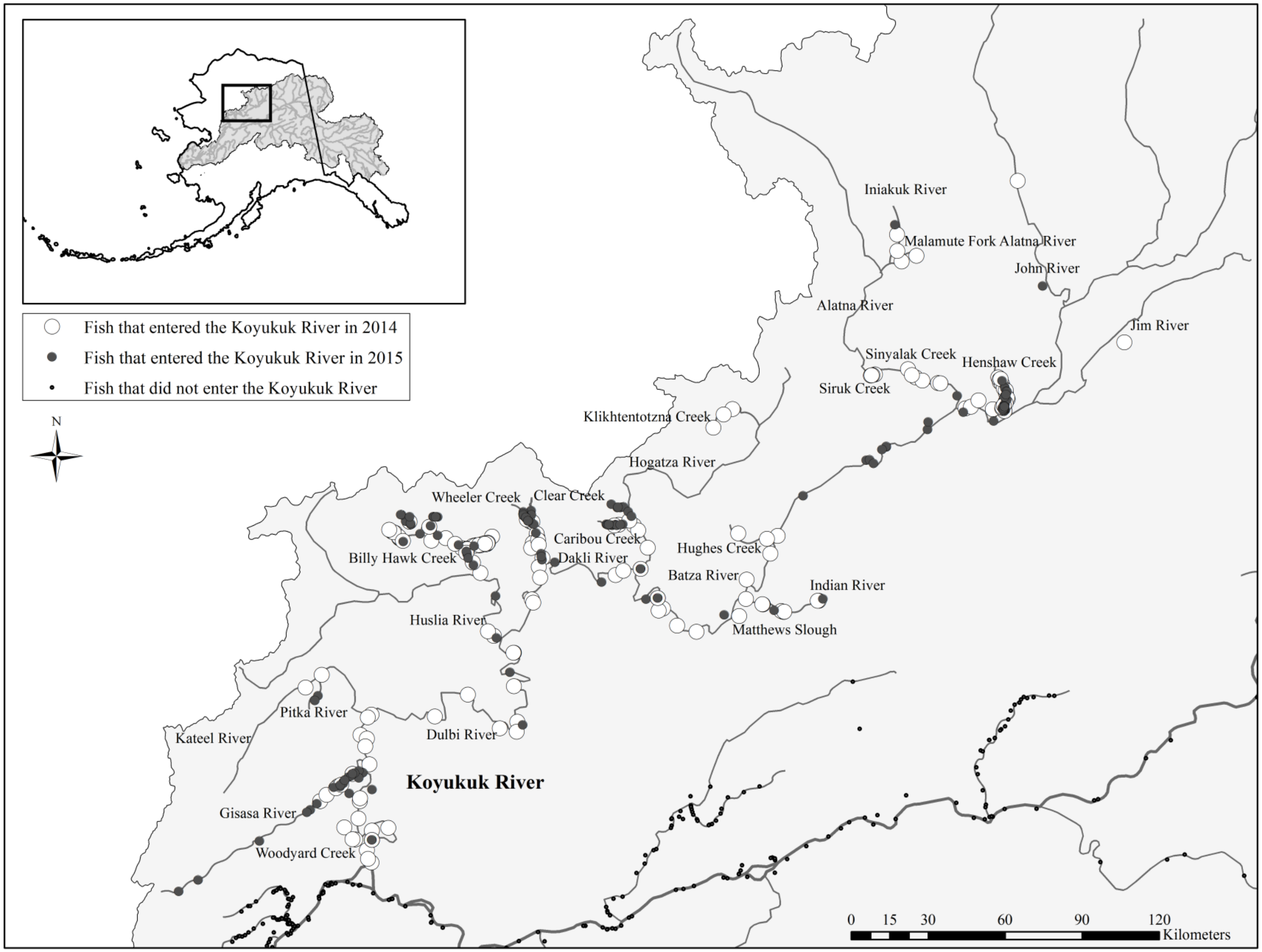


Figure 20.–Final locations of tagged summer chum salmon within the Koyukuk River drainage in 2014 and 2015.

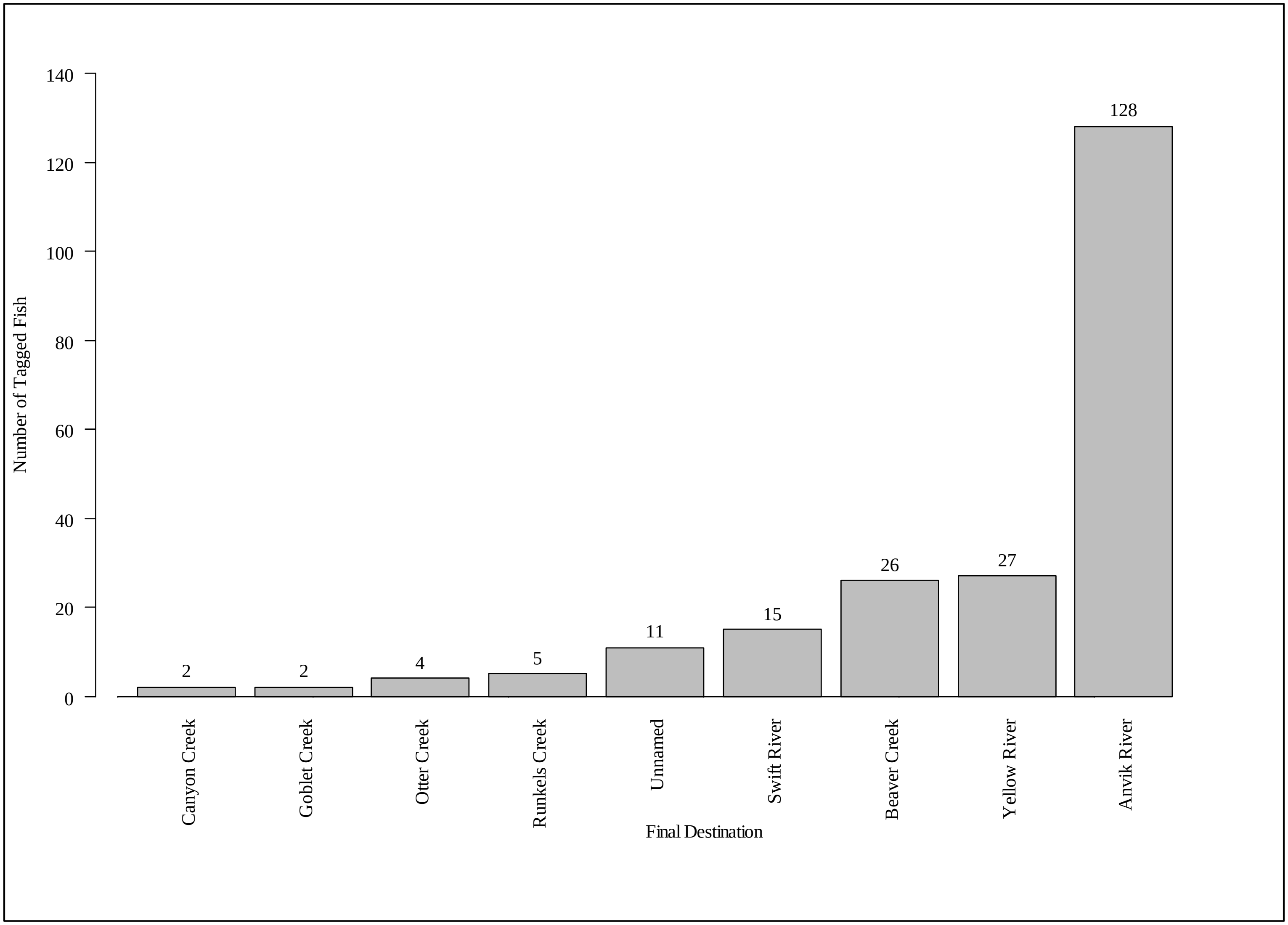


Figure 18.–Number of tagged summer chum salmon that entered tributaries within the Anvik River drainage or remained on the mainstem Anvik River in 2014.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

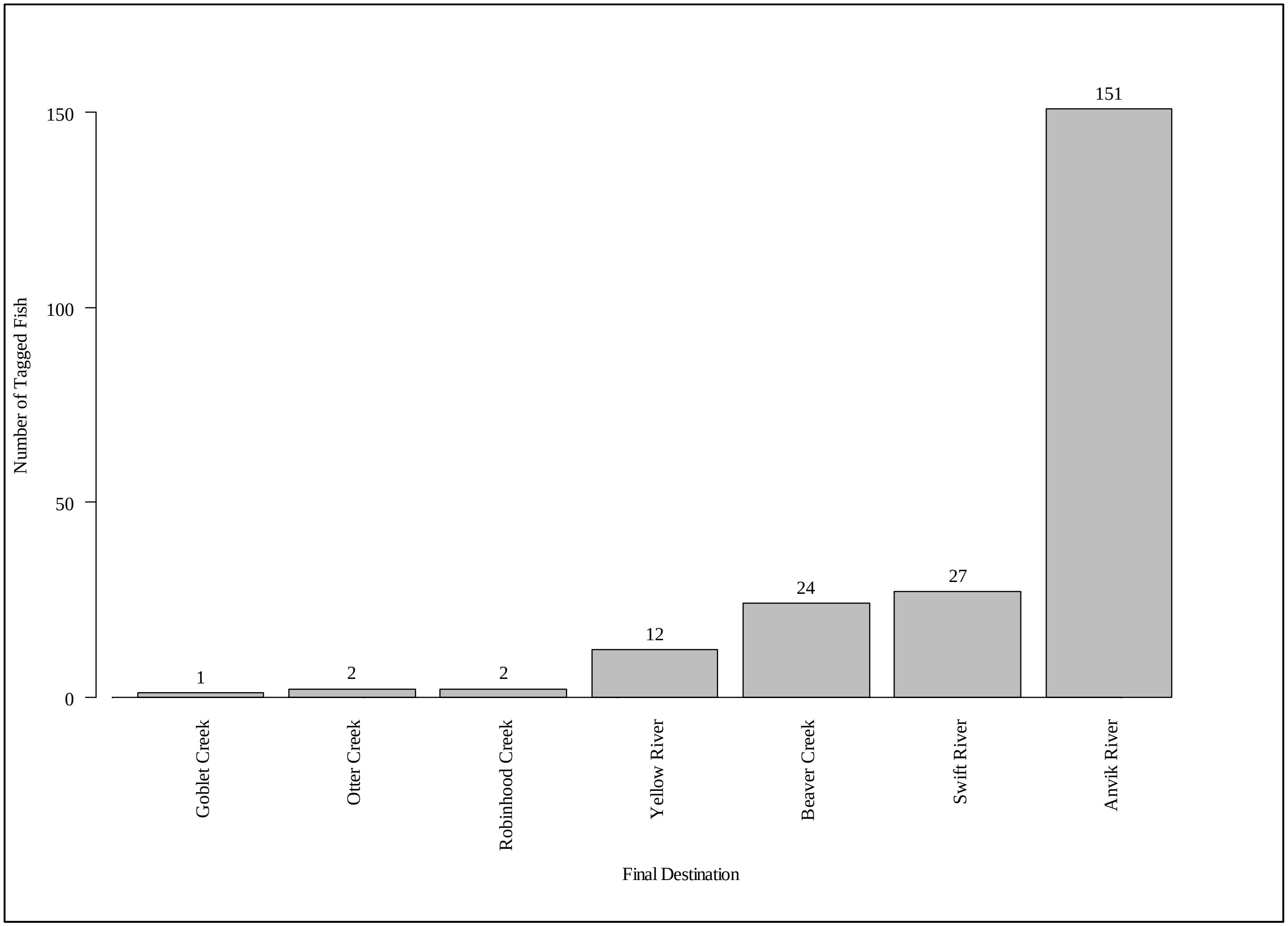


Figure 19.–Number of tagged summer chum salmon that entered tributaries within the Anvik River drainage or remained on the mainstem Anvik River in 2015.

Note: Total numbers of tagged summer chum salmon assigned to each final destination are located above the bars.

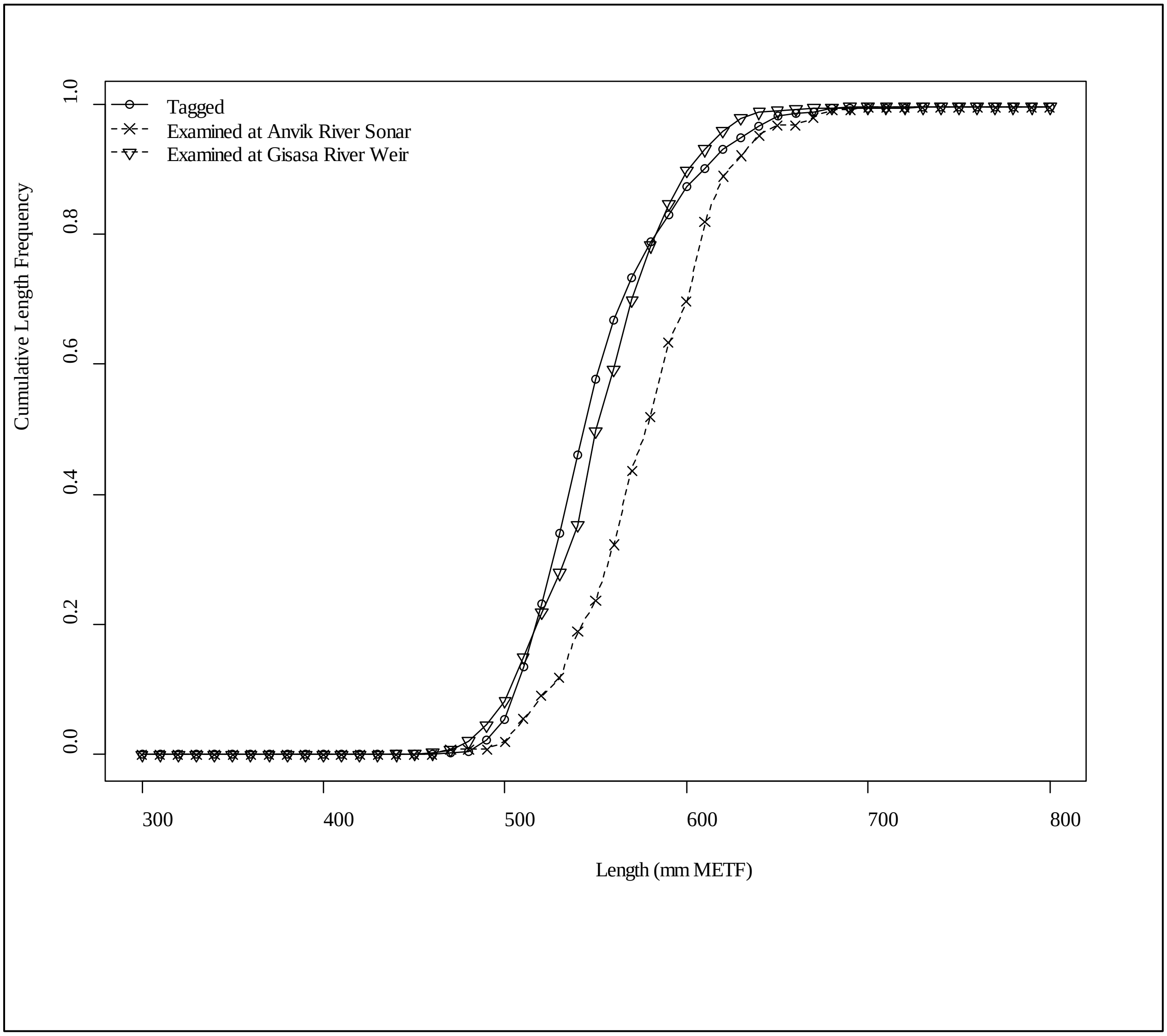


Figure 23.–Cumulative relative length frequencies of summer chum salmon tagged near Russian Mission compared with the cumulative length frequencies of fish examined during sampling at the Anvik River sonar and Gisasa River weir in 2014.

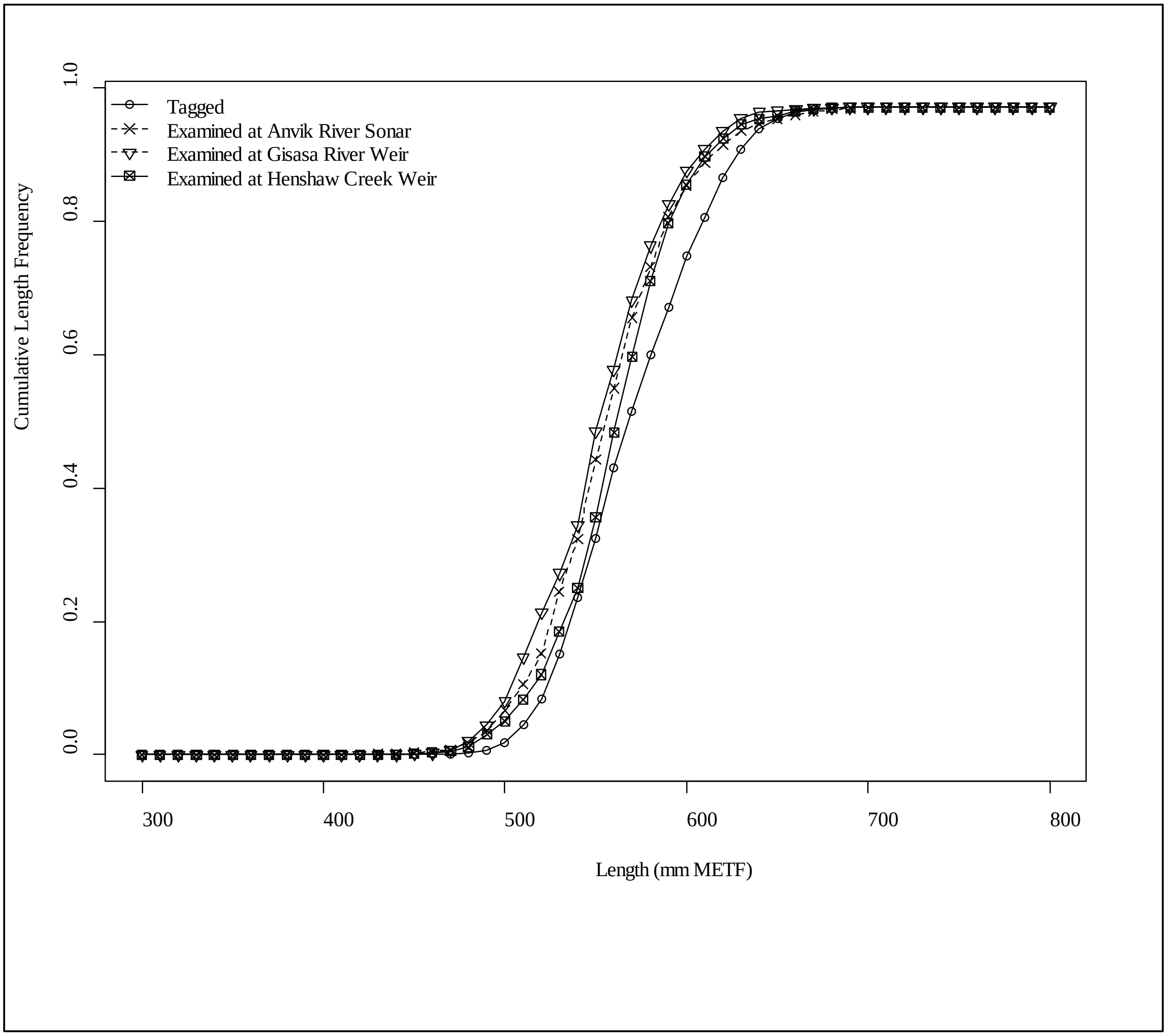


Figure 24.–Cumulative relative length frequencies of summer chum salmon tagged near Russian Mission compared with the cumulative length frequencies of fish examined during sampling at the Anvik River sonar, Gisasa River weir, and at the Henshaw Creek weir in 2015.

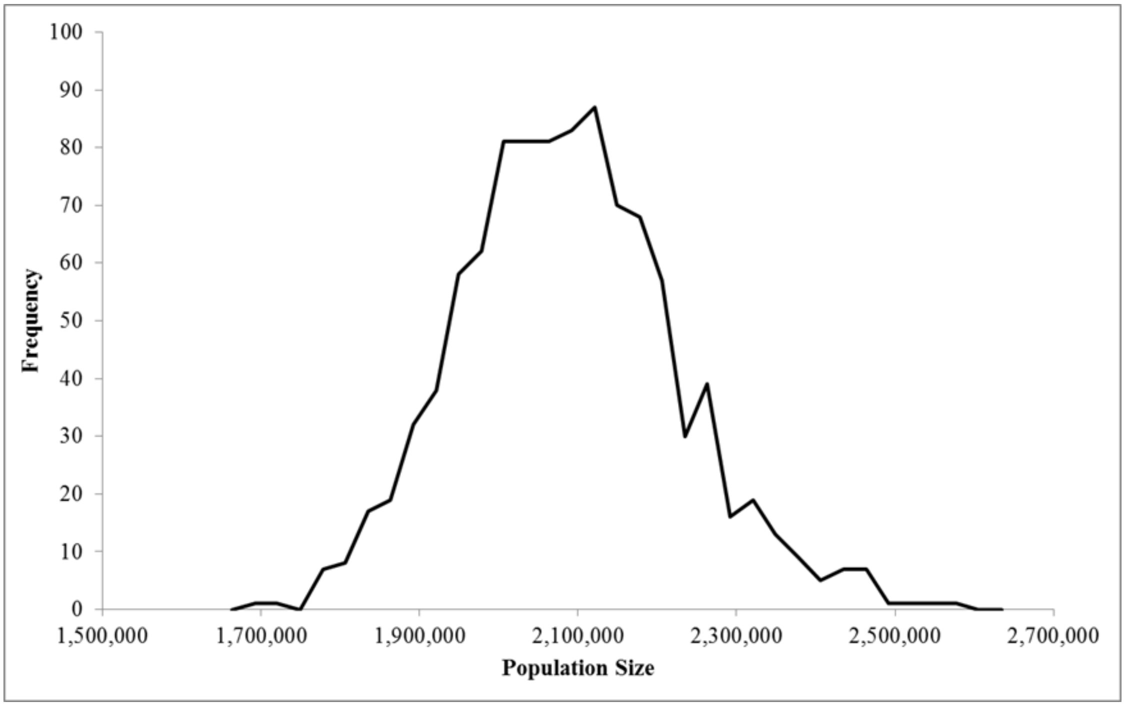


Figure 25.–Frequency distribution of mark–recapture abundance estimates, based on parametric bootstrap sampling with 1,000 replications, in 2014.

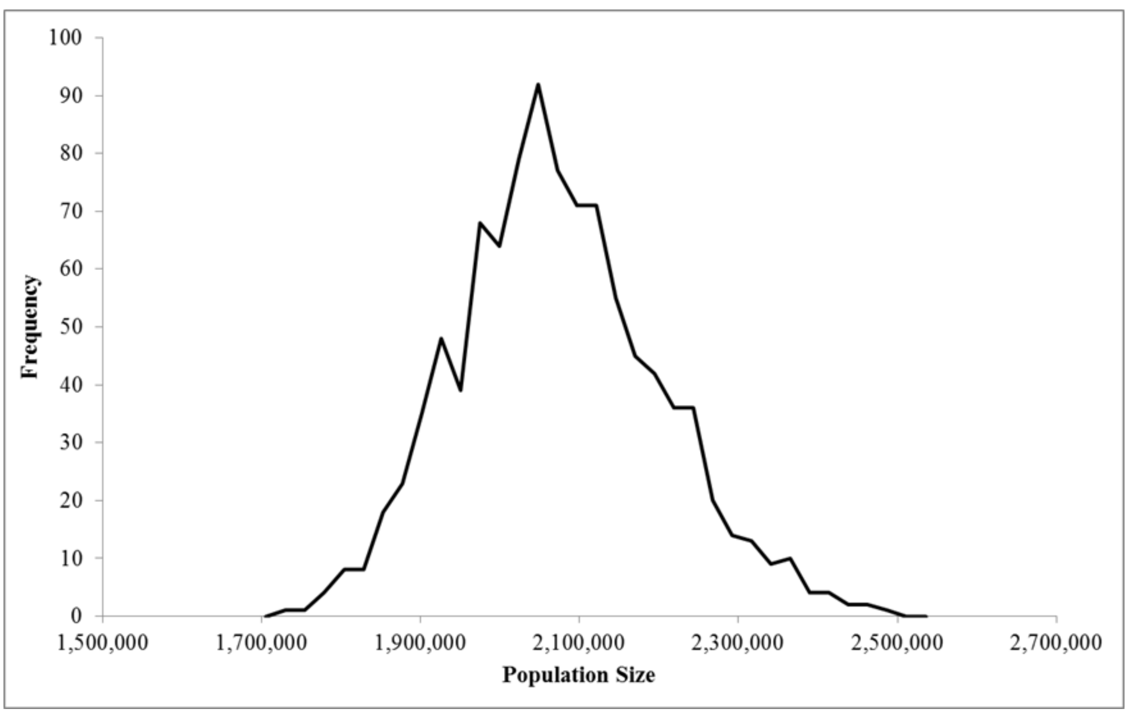


Figure 26.–Frequency distribution of mark–recapture abundance estimates, based on parametric bootstrap sampling with 1,000 replications, in 2015.

APPENDIX A

Appendix A1.–Deployment rate of radio transmitters (based on run timing and daily passage estimates from the Pilot Station sonar) for summer chum salmon captured by drift gillnet near Russian Mission in 2014 and 2015.

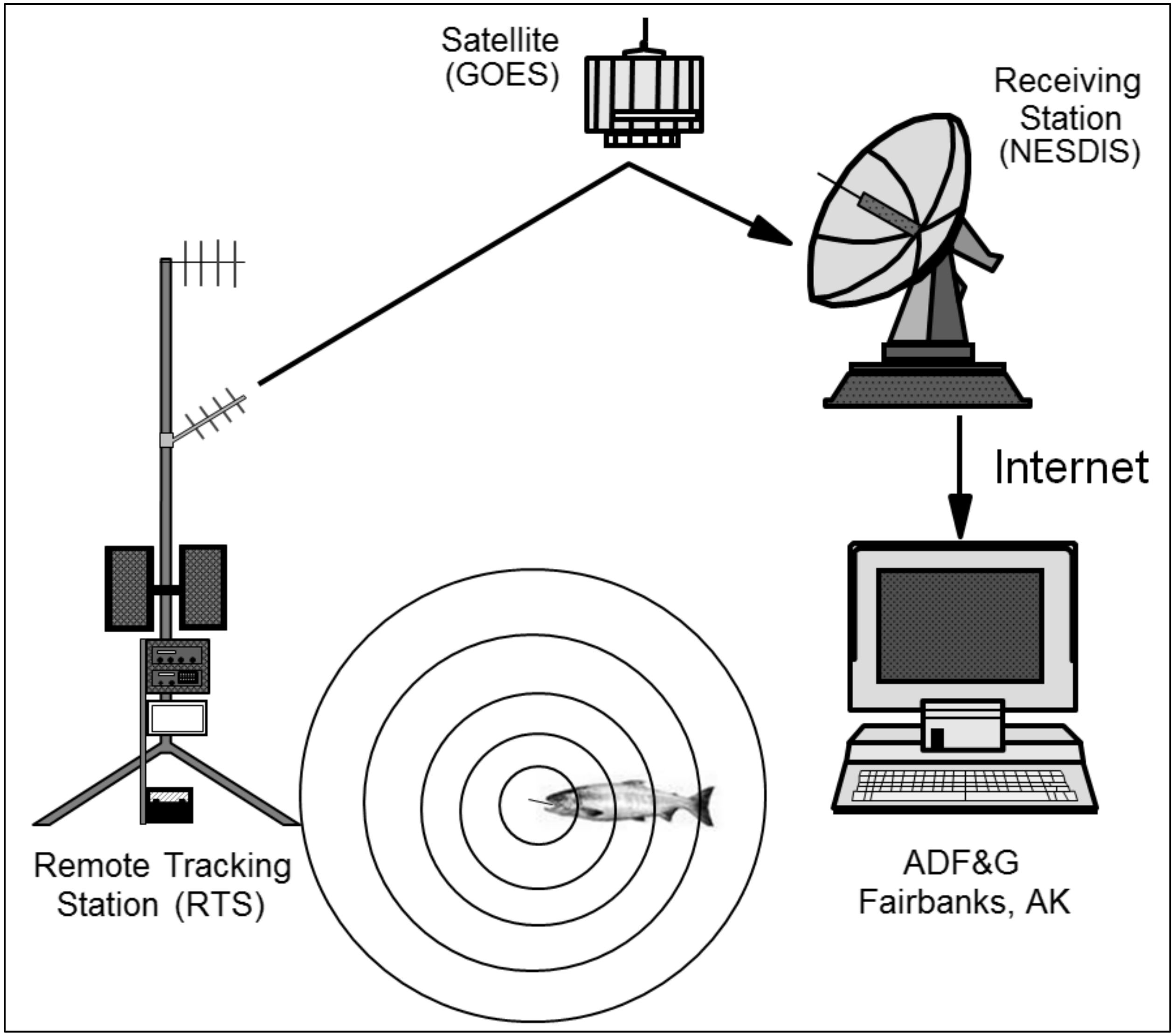
	2014		2015	
Date	Tags deployed	Tags deployed per week week	Tags deployed	Tags deployed per week
12 Jun	5		11	
13 Jun	8		12	
14 Jun	8		8	
15 Jun	20		9	
16 Jun	23		8	
17 Jun	29		18	
18 Jun	27	120	13	79
19 Jun	36		34	
20 Jun	44		38	
21 Jun	43		30	
22 Jun	50		34	
23 Jun	59		48	
24 Jun	64		56	
25 Jun	64	360	32	272
26 Jun	96		15	
27 Jun	74		12	
28 Jun	70		68	
29 Jun	73		31	
30 Jun	62		89	
1 Jul	60		103	
2 Jul	42	477	74	392
3 Jul	28		52	
4 Jul	24		22	
5 Jul	41		21	
6 Jul	35		50	
7 Jul	16		54	
8 Jul	24		26	
9 Jul	36	204	33	258
10 Jul	35		17	
11 Jul	16		15	
12 Jul	10		12	
13 Jul	10		17	
14 Jul	–		25	
15 Jul	–		14	
16 Jul	–	71	16	116
17 Jul	–		16	
18 Jul	–		17	
19 Jul	–		15	
20 Jul	–		17	
21 Jul	–		917	82
Total	1,232	1,232	1,199	1,199

Appendix A2.–Name, distance from the tagging site near Russian Mission, and the coordinates for each remote tracking station used to locate tagged summer chum salmon in 2014 and 2015.

Tower name	Distance from tagging site (km)	Latitude	Longitude
Russian Mission	-28.0	61.784	-161.318
Paimut Station	21.8	61.961	-160.345
Bonasila River	141.9	62.540	-160.266
Mainstem Anvik River	167.1	62.789	-160.080
Anvik River	176.6	62.654	-160.453
Anvik River Sonar	208.9	62.737	-160.679
Innoko River	289.1	63.073	-159.052
Nulato River	428.2	64.713	-158.192
Lower Koyukuk River	484.8	65.022	-157.541
Yuki River	558.3	64.726	-156.144
Gisasa River	559.5	65.250	-157.732
Melozitna River	604.8	64.791	-155.558
Nowitna River	743.1	64.658	-154.506
Raven Ridge	850.5	65.381	-150.892
Manley (Tanana River)	877.5	64.979	-150.823
Hogotza River	912.1	66.006	-155.365
Kantishna River	949.6	64.701	-150.020
Upper Koyokuk River	953.0	65.905	-155.215
Tolovana River	958.7	64.901	-149.878
Nenana (Tanana River)	1054.8	64.582	-148.924
Chena River	1137.7	64.840	-147.817
Salcha River	1201.8	64.479	-146.890
Upper Tanana River	1246.1	64.258	-146.290
Tanana River Mainstem	1353.9	63.896	-144.821

Note: The Russian Mission tracking station was used to detect tagged fish that dropped out of the study area, possibly due to handling effects, and was only active during 2015.

Appendix A3.–Remote tracking station and satellite uplink diagram used to collect and access movement information of summer chum salmon in the Yukon River drainage study area.



Appendix A4.–Aerial survey routes during the survey of tagged summer chum salmon in 2014 and 2015.

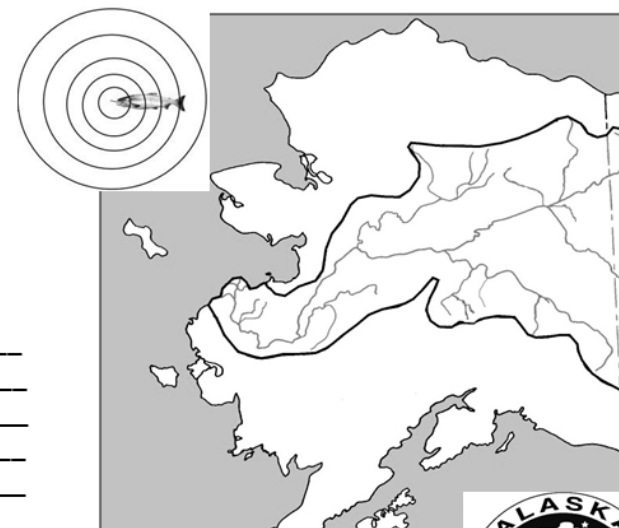
Survey Name
Tanana River Mainstem (MS)
Yukon River MS and tributaries from Eagle Island to Russian Mission
Yukon River MS and tributaries from Russian Mission to Fairbanks
Yukon River MS and tributaries Russian Mission to Aniak to Fairbanks
Raven Ridge to Yukon River MS to Russian Mission
Tozitna and Koyukuk rivers
Yukon River MS from Kaltag to Bonasila to Russian Mission
Yukon River MS from Fairbanks to Marshall
Yukon River MS from Fairbanks to Anvik
Yukon River MS from Tanana River confluence to Koyukuk River tributaries
Koyukuk River tributaries to Yukon River MS to Tanana to Fairbanks
Chatanika River, Nenana River, Lost Slough, and Salcha River
Melozitna and Koyukuk Rivers
Hogotza River
West Fork Andreafsky River Drainage
Yukon River MS from Yukon bridge to Melozitna River
Andreafsky River drainage
Upper Koyukuk River
Sheenjek and Chandalar rivers

Appendix A5.–Public tag recovery poster that was distributed to various villages along the Yukon River to encourage reporting of harvested summer chum salmon.

Where do summer chum salmon go in the Yukon River drainage?
Radio telemetry can help answer important fishery management questions.

- Distribution in tributaries
  - Proportions compared to Mainstem sonar at Pilot Station
  - Relationship to Anvik sonar
  - Weir/tower/test fish monitoring
- Stock run timing
- Migration rates

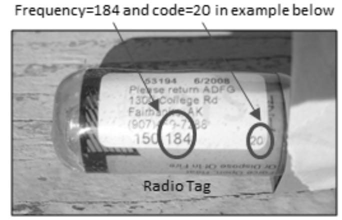
Harvest + Escapement = Total Run Size



External Tag number: ______________ Color: ___________
Radio Tag Frequency: __________ Tag Code: ___________
Date Caught: _____________ Total Chum/Event: _________
Gear: Net/Mesh_________, Fish Wheel, Other___________
Capture Location: ________________________________
Gender of fish (circle one): M or F or Unknown
Radio tag found (circle one): Inside or Outside of Fish?
Fishery (circle one): Subsistence – Commercial – Personal Use

Provide contact info if you want the results from your fish?
Name: ____
Phone Number: _______________________
Mailing Address ___________________________________
City _________________ State ______ Zip code ________

Frequency=184 and code=20 in example below



Agency Information:
Date Recorded: ____________________________
Print Name of data recipient: _________________________

Division of Commercial Fisheries
Anchorage 907-267-2104
Fairbanks 907-459-7274
(Collect Calls Accepted)
stephanie.schmidt@alaska.gov
or return to traditional council