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Kuskokwim River Sockeye Salmon Investigations, 2006 and 2007

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

FISHERY MANUSCRIPT NO. 11-04

KUSKOKWIM RIVER SOCKEYE SALMON INVESTIGATION, 2006 AND 2007

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PREFACE

ABSTRACT

The role of sockeye salmon *Onchorhynchus nerka* in the environment and its importance to the culture and economy of the Kuskokwim River is changing. There is growing interest in commercial harvest, but little is known about the biology and ecology of Kuskokwim River sockeye salmon. This project addressed this information gap by 1) describing the location, relative abundance, and run timing of Kuskokwim River sockeye salmon spawning aggregates, 2) describing and comparing habitat utilization and seasonal migration patterns of river-type and lake-type juveniles, 3) describing and comparing smolt size and growth among tributaries and habitat types, and 4) describing the relative importance of river-type versus lake-type sockeye salmon to total production of Kuskokwim River sockeye salmon. This project also included outreach and capacity building elements that will hopefully provide a foundation for more effectively incorporating project findings into the long-term fishery management program, much of which involves public process and support.

Key words: Kuskokwim River, Holitna River, Telaquana Lake, sockeye salmon, *Oncorhynchus nerka*, river-type, lake-type, distribution, migration timing, habitat use, growth, community outreach, capacity building, fishery management

OVERVIEW OF SOCKEYE SALMON BIOLOGY AND ECOLOGY IN THE KUSKOKWIM RIVER

Information about the behavior, biology, and ecology of sockeye salmon *Oncorhynchus nerka* in the Kuskokwim River drainage is largely limited to adult observations from commercial and subsistence harvests, limited mainstem studies, and escapement into a few tributaries. Our understanding of upriver migration timing is based on gillnet catches of sockeye salmon in the lower river at Bethel (Bue 2005) and fish wheel catches at Kalskag (Schaberg et al. 2010) from June through August and lacks stock specificity. Age and size structure estimates of adult sockeye salmon is the result of sampling commercial harvests and adults migrating up two tributaries. Although escapement monitoring projects are maintained throughout the drainage (Figure 1), their placement is mostly a function of Chinook *O. tshawytscha* and chum salmon *O. keta* abundance. Only one weir project located in the upper Holitna drainage counts substantial numbers of sockeye salmon. This project, located on the Kogrukluk River, has operated since the late 1970s, and has reported counts of sockeye salmon numbering from 1,700 to 60,000 fish (Liller et al. 2008). Related exploratory surveys conducted in 1977 and 1978 in the Holitna and Hoholitna River drainages noted the presence of adult and juvenile sockeye salmon in side sloughs of these rivers, and suggested these areas were used because of clear water upwelling in the gravel (Baxter[1] 1979). Another weir located on the Kwethluk River has monitored the migration and age structure of up to 3,400 sockeye salmon since 1997 (Roettiger et al. 2005), and recently the Salmonid Rivers Observatory Network (SaRON) project has begun to evaluate habitat use by salmon in this drainage (www.umt.edu/flbs/Research/SaRON.htm, Stanford et al. 2005). However, these and other small populations of sockeye salmon noted throughout the

[1] Baxter, R. Undated. Hoholitna River reconnaissance survey, 1977. Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region Kuskokwim Salmon Resource Report No. 3, Anchorage.

Kuskokwim River drainage were thought to be incidental, since sockeye salmon are typically associated with rivers that provide access to lake habitat for juvenile rearing for one to two years, such as those found in Bristol Bay sockeye salmon systems (Burgner 1991). Thus, until recently, biologists believed that the Stony River drainage and its associated lake system contained the largest population of Kuskokwim River salmon.

BRIEF HISTORY OF THE KUSKOKWIM RIVER SOCKEYE SALMON FISHERIES

Information regarding the subsistence harvest of sockeye salmon is not well documented before 1989 when the subsistence harvest tended to be defined as "Chinook salmon" and "small salmon" (Simon et al. 2007). Long-time area residents, however, noted an increase in the use of sockeye salmon as a subsistence food (James Charles, resident, Tuntutuliak, personal communication). Since 1989, subsistence harvests of sockeye salmon in the Kuskokwim Area have ranged between 15,336 and 39,272 fish, with a recent 10-year average of 22,959 fish (2000–2009; Hamazaki *In prep*). In recent years, most of this harvest occurred in the lower river and likely during the early portions of the run before the influx of chum salmon. It is unknown what percentage of the total return is harvested for subsistence use, and to what degree the historical harvest timing affects specific spawning aggregates of sockeye salmon.

Inriver commercial harvest of sockeye salmon has likely been occurring since the early 1900s (Pennoyer et al. 1965), but there has not been a formal directed fishery until recently. The recent 10-year average commercial harvest has been lower than historical harvests, partially due to weak returns of other targeted species and diminishing fishing effort that has been the result of lower prices paid to fishermen for all salmon species after the mid-1990s (Ward et al. 2003; Whitmore et al. 2008). Notwithstanding the diminished commercial market, there has been an interest in recent years for a directed fishery for sockeye salmon in the Kuskokwim River, mostly due to the premium market value of the species. In response to this interest, in 2004 the Alaska Board of Fisheries formally established a limited guideline commercial harvest level of 0–50,000 sockeye salmon, a decision guided by the Alaska Sustainable Salmon Fisheries Policy which states: "In the face of uncertainty, salmon…fisheries…shall be managed conservatively." Further development of this fishery, however, is impeded by the lack of knowledge about Kuskokwim River sockeye salmon runs.

Concurrent with the developing commercial interest in sockeye salmon is a diminished interest in chum salmon, which is the most abundant salmon species in the Kuskokwim River during late June and July. The run timing of sockeye and chum salmon overlap in the commercial fishing district, and processors wanting to avoid chum salmon are most interested in buying sockeye salmon from the early part of the run in order to avoid harvesting chum salmon. Again, it is unknown whether harvesting only from the early portion of the sockeye salmon run is inadvertently targeting specific spawning aggregates and excluding others.

Knowledge of stock-specific run timing information is important in order to understand the population structure of Kuskokwim River sockeye salmon and the possible effects of mixed-stock harvest. There is some evidence of stock-specific run timing for Kuskokwim River sockeye salmon from tagging conducted at Kalskag and Aniak from 2002 to 2006 (Figure 2), but information is limited by few tag recovery locations (Schaberg et al. 2010). In other rivers, differences in run timing have been seen between spawning aggregates, most often noted between tributary- and lake-spawning populations (Burger et al. 1995). However, an earlier mean arrival date for populations with longer migration distances within a complex system has been noted (e.g., Merritt and Roberson 1986; Hodgson and Quinn 2002). These timing differences probably represent the needs of offspring (Brannon 1987; Boatright et al. 2004) and likely reflect significant genetic differences between runs (Wilmot and Burger 1985). Existing data suggests a high degree of genetic diversity among Kuskokwim River sockeye salmon populations; specifically, the two life history strategies (river and lake spawners) are highly divergent (Figure 3; Dann et al. 2009). Timing of return migration and spawning tend to be highly heritable traits (Hodgson and Quinn 2002), and may be very precise, as in the Fraser River (Rand and Hinch 1998; English et al. 2005). However, there may be much overlap between timing of specific populations, which may be a concern for harvest managers (Jensen and Mathisen 1987). The identification of stocks within a harvest area at a given time allows managers the opportunity to assess the affect of fishing on individual stocks or groups of stocks, which is important because the capacity and productivity of different stocks may vary (Merritt and Roberson 1986). If this is not achieved, it is possible that overharvest of weaker or smaller spawning aggregates may result in depression or even elimination of some populations (e.g., Saunders 1981; Beacham et al. 1987; Collie et al. 1990; Policansky and Magnuson 1998).

REPORT STRUCTURE AND GOAL

Prior to this project, managers had very little information on the distribution or run timing of specific spawning aggregates of sockeye salmon, and even less information on life history characteristics or habitat needs. Without analysis of population structure, it is difficult to analyze the effects of harvest in mixed-stock fisheries. Without analysis of life history characteristics, distribution, habitat use, and growth, it is difficult to assess what effects future human development could have on important spawning and rearing areas.

This document presents the findings from three separate but complimentary efforts directed at describing the life history characteristics of Kuskokwim River sockeye salmon. In Chapter 1, we present new information on the distribution, relative abundance, and stock-specific run timings of Kuskokwim River sockeye salmon. In Chapter 2 we explore the freshwater growth, habitat use, and life history characteristics of juvenile sockeye salmon. In Chapter 3 we describe the various outreach and capacity building aspects associated with these projects, through which we strived to develop a sense of community understanding, ownership, and trust. Because of the timing and interconnectedness of these efforts, we have chosen to package them together in a convenient single source document in order to provide a broad-scale perspective on Kuskokwim River sockeye salmon. Together, this is the first step in understanding the trends and causes of variation of the species, and in developing stakeholder support to more effectively fold this new information into the fishery management process.

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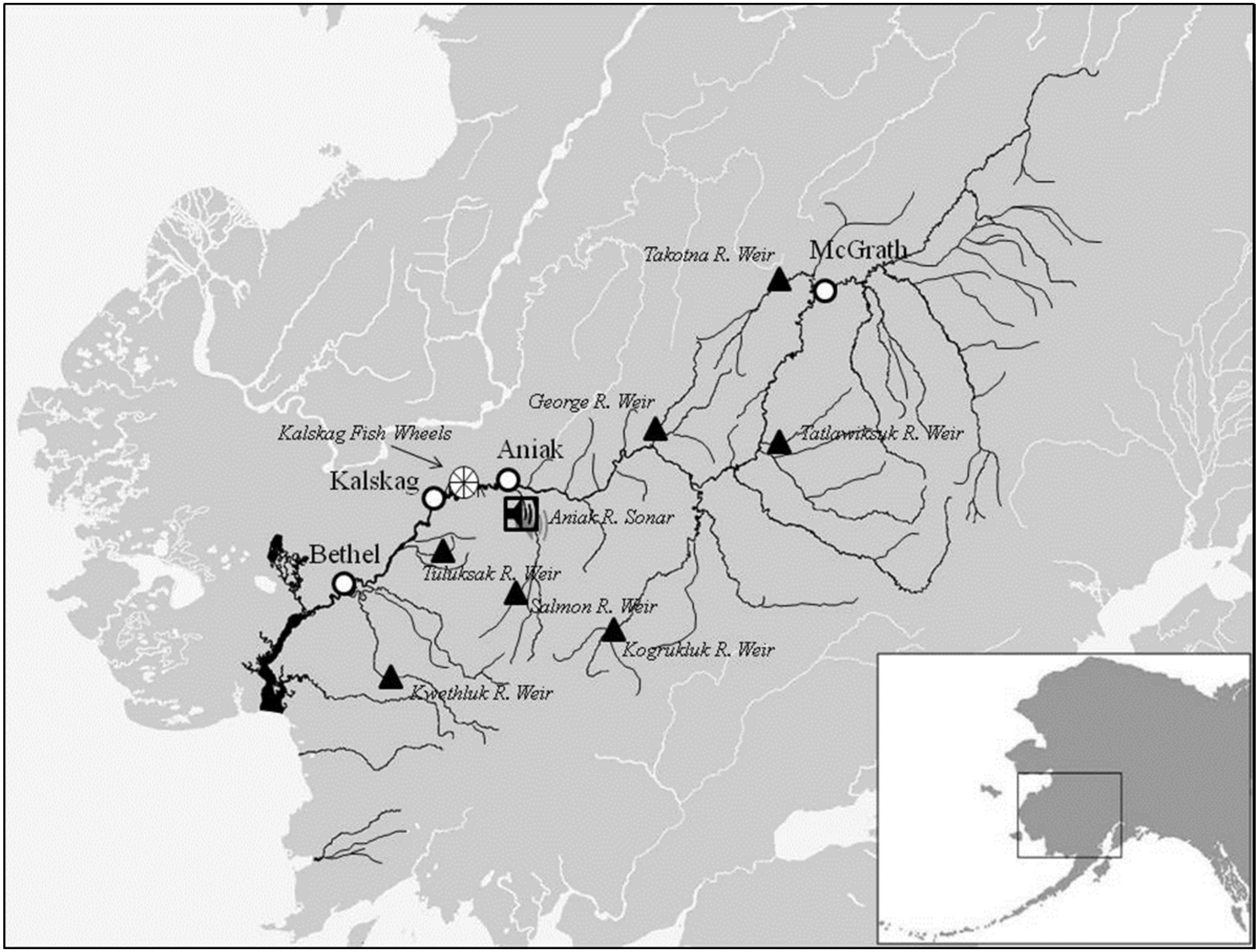


Figure 1.–Kuskokwim River drainage highlighting inriver salmon escapement monitoring locations.

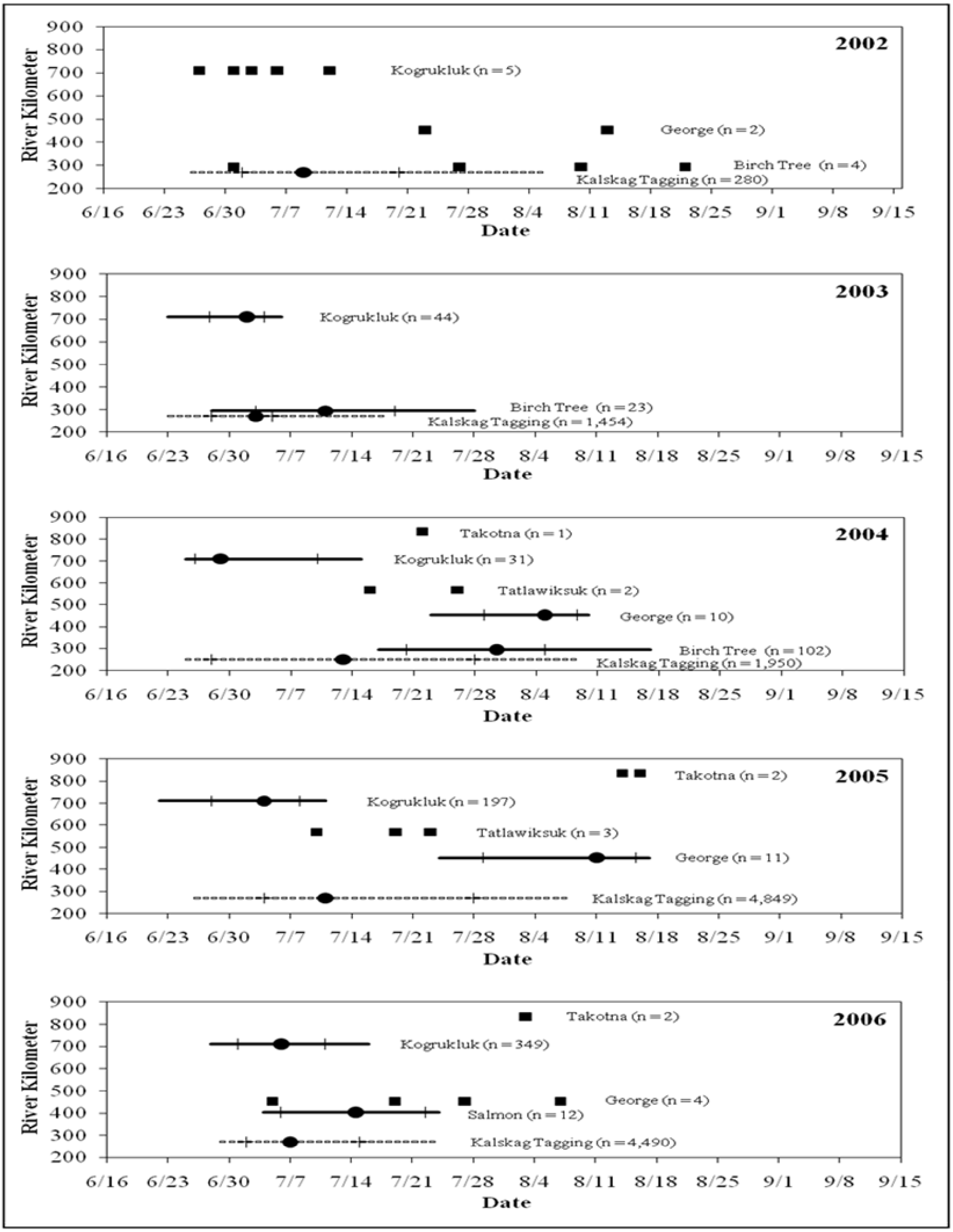
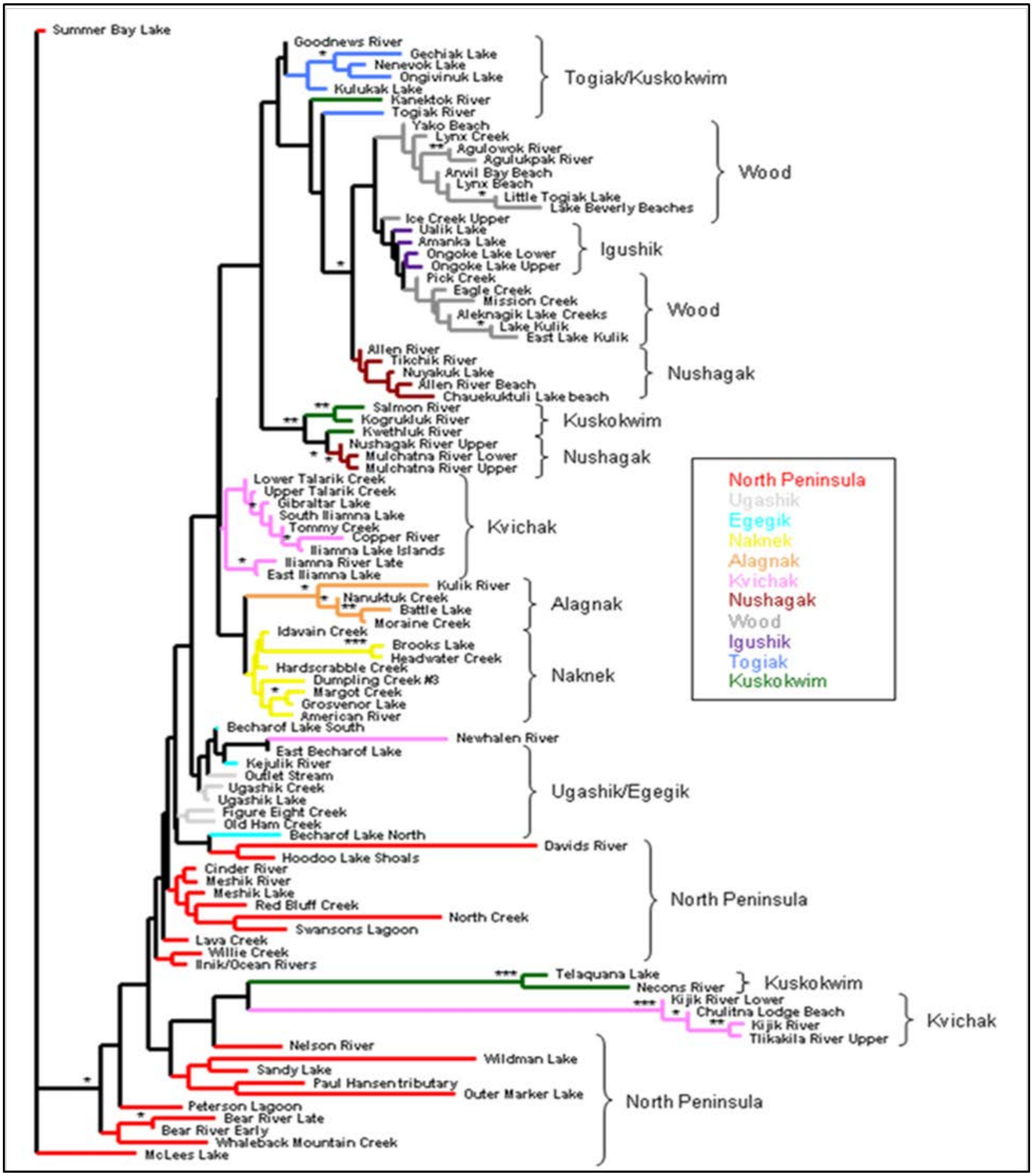


Figure 2.–Run timing for sockeye salmon tagged near Kalskag and recaptured in upriver tributaries of the Kuskokwim River, 2002–2006.



Source: Dann et al. 2009.

Note: Bootstrap consensus nodes*** =95-100%; ** =70-95%; * =50-70%.

Figure 3.–Consensus N-J tree based on the genetic distances between sockeye salmon sampled from spawning areas draining Bristol Bay, Alaska Peninsula, and Kuskokwim Area.

CHAPTER 1. ADULT SOCKEYE SALMON DISTRIBUTION, STOCK-SPECIFIC RUN TIMING, AND STOCK-SPECIFIC MIGRATION RATE

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ABSTRACT

The role of sockeye salmon in the environment and their importance to the culture and economy of the Kuskokwim River is changing. There is growing interest in directed commercial harvest of this species as demonstrated by recent actions taken by the Alaska Board of Fisheries that will allow directed commercial harvest on sockeye salmon under a guideline harvest level. Lacking, however, is fundamental knowledge about distribution, abundance, and basic biology and ecology of sockeye salmon in the Kuskokwim River. Our goal was to begin addressing these data gaps by describing the relative spawning distribution, stock-specific run timing, and stock-specific migration rate. We achieved these objectives by conducting radiotagging studies in 2006 and 2007. Results indicate that river-type sockeye salmon are far more prevalent than previously believed, particularly those spawning in the Holitna River basin, which accounted for about 70% of the final destination of tagged fish. Other major contributors included the Stony River (lake-type), and Aniak River (river-type). River-type sockeye salmon tend to have more volatile productivity than lake-type populations, so given the dominance of river-type fish, fisheries managers should anticipate highly variable annual returns that may be difficult to forecast. Stock-specific run timing for the three major stocks overlapped broadly, which will provide additional management challenges to ensure adequate escapement between stocks that likely have very different productivity. Future measures should include establishing an escapement monitoring program representative of the stock diversity found within Kuskokwim River sockeye salmon, including escapement goals.

Key words: Holitna River, Stony River, Aniak River, Aniak Lake, Kogrukluk River, Telaquana Lake, Necons River, Two Lakes, Kuskokwim River, distribution, stock-specific, run timing, migration rate, radiotelemetry, tagging, fish wheels, weirs, subsistence fishing, commercial fishing, salmon fishery management, sockeye salmon, *Oncorhynchus nerka*

INTRODUCTION

Five species of anadromous Pacific salmon *Oncorhynchus* spp return to the Kuskokwim River each year and support an average annual subsistence and commercial harvest of nearly one million fish, with sockeye salmon *O. nerka* accounting for only about 70,000 (range 26,000–162,000) of the harvest (Whitmore et al. 2008). In recent years, however, long-time residents of the Kuskokwim River have noted an increase in the occurrence of sockeye salmon as a subsistence food (James Charles, resident, Tuntutuliak, personal communication). There has also been interest in developing a directed commercial sockeye salmon fishery, which prompted the Alaska Board of Fisheries in 2004 to formally establish a limited annual guideline commercial harvest level of 0–50,000 sockeye salmon (5 AAC 07.365; Bergstrom and Whitmore 2004). In accordance with the Alaska Sustainable Salmon Policy (5 AAC 39.222), fishery managers must use a precautionary approach in implementing this sockeye salmon directed fishery because of the lack of fundamental information about sockeye salmon distribution, abundance, and run dynamics. Indeed, at the time of this study, there were no escapement goals established for sockeye salmon in the Kuskokwim River, and sockeye salmon generally had a low occurrence at the current array of tributaries where salmon escapements were monitored.

Of the tributaries monitored (Figure 1.1), the largest numbers of sockeye salmon occur at the Kogrukluk River weir located in the upper Holitna drainage, where annual escapements ranged from 1,700 to 60,000 fish (Liller et al. 2008). Kwethluk River ranks second with annual escapements ranging from a few hundred to 6,732 fish (Miller et al. 2007, 2008). Sockeye salmon number fewer than 1,000 fish in the Tuluksak, George, Tatlawiksuk, and Takotna rivers as evidenced by weir counts. Like most of the Kuskokwim River drainage, neither Kogrukluk nor Kwethluk rivers have the large lakes that are typically associated with significant production (Burgner 1991), so sockeye salmon occurrence at these and other monitored tributaries had been thought incidental. Most Kuskokwim River sockeye salmon production was assumed to have been from Telaquana Lake, in the upper Stony River drainage, where observations of sockeye salmon are periodically documented from aerial surveys, though viewing conditions are nearly always poor due to suspended glacier flour (Burkey and Salomone 1999).

Sockeye salmon exhibit a variety of life history strategies throughout their range. They are typically associated with rivers that provide access to lake habitat where juveniles rear for one to two years prior to smolting, referred to as following a "lake ecotype" life history strategy (Wood et al. 2008). Sockeye salmon from tributaries with no associated lake system follow the "river ecotype" life history strategy where, following emergence, juveniles rear and overwinter in river channel and slough habitats where water velocity is slow. River-type populations are not abundant across the Pacific Rim, though small populations are reported throughout much of the species range (e.g., Wood et al. 1987; Burgner 1991; Gustavson and Winans 1999; Eiler et al. 1992). Some watersheds also produce 0-check or "sea ecotype" sockeye salmon that spend at most a few months after emergence in river habitats before smolting (Wood et al. 2008). These three life history strategies likely reflect differences in productivity as demonstrated by differences in sizes, ages, and fecundities of spawning adults (Rogers 1987; Blair et al. 1993), in high heterogeneity in sizes of riverine juveniles (Wood et al. 1987), and differences in genetic diversity and genetic structure (Beacham et al. 2004; Gustafson and Winans 1999; McPhee et al. 2009).

Given these different life history strategies and the likely resulting differences in productivity, it is important to have knowledge of stock-specific run timing through mixed-stock fisheries such as in the lower Kuskokwim River. In other rivers, differences in run timing have been seen between spawning aggregates (stocks), most often noted between tributary spawning- and lake-spawning populations (Burger et al. 1995). An overlap in run timing of specific populations and life history types may be a concern for harvest managers, since the capacity and productivity of different stocks may vary (Merritt and Roberson 1986). Overharvest of smaller spawning aggregates could result in depression or elimination of some populations (e.g., Policansky and Magnuson 1998). Previously, there has been very little information on the spawning distribution, relative abundance, or stock-specific run timing of Kuskokwim River sockeye salmon with which to base sustainable management practices.

OBJECTIVES

In this study, we used radiotelemetry based at the Kalskag fish wheel tagging platform in 2006 and 2007 to achieve the following:

1. Describe the distribution and relative abundance of spawning sockeye salmon aggregates (stocks) among tributaries of the Kuskokwim River upstream of Kalskag (rkm 270).
2. Estimate stock-specific run timing and stock-specific migration rates in the mainstem Kuskokwim River.
3. Describe the relative importance of river-type versus lake-type sockeye salmon to total sockeye salmon production in the Kuskokwim River.

METHODS

CAPTURE AND TAGGING

Adult sockeye salmon were captured in 2006 and 2007 on the mainstem Kuskokwim River (Figure 1.1), fitted with radio and/or anchor tags, and tracked to locations throughout the drainage using aerial and ground-based tracking. Captures were made at approximately rkm 270 using two fish wheels operated from early June to mid-August. This platform has tagged fish since 2001 and is the farthest downstream point above commercial fishing districts where fish wheels are effective to capture salmon (Schaberg et al. 2010). Fish wheels were operated seven days per week in 2006, and six days per week in 2007, for about nine hours each day during daylight hours. One fish wheel was located along the north bank and one along the south bank, each was equipped with a live box for holding fish prior to tagging. Throughout each day, a two to three person crew rotated between two fish wheels to remove fish from the holding box and deploy tags. At each inspection, all fish were netted from the live box, the number of each species caught was recorded, and species other than sockeye salmon were immediately released. Each time a sockeye salmon was netted, it was immediately placed in a tagging cradle that was submerged in a tub of continuously refreshed river water. Fish were not anesthetized.

Fish were tagged with pulse-coded esophageal radio transmitters manufactured by Advanced Telemetry Systems (Isanti, Minnesota).[2] Transmitters were individually distinguishable by a unique encoded pulse pattern and frequency. Ten frequencies spaced approximately 20 kHz apart with 50 encoded pulse patterns per frequency were used for a total target of 500 uniquely identified tags in each year of the study. Radio tags were inserted through the esophagus and into the upper stomach using a narrow piece of polyvinyl chloride (PVC) tubing so that the antenna end was seated approximately 0.5 cm anterior to the base of the pectoral fin. Results from a 2005 feasibility study suggest that tagging fish <400 mm mideye to fork (MEF) length results in a higher potential risk of stomach rupture (Appendix 1.A); therefore, fish shorter than 400 mm MEF length were not tagged in this study (estimated <7% of the population based on length measurements taken at the Kalskag tagging site in 2002 and 2003).

Efforts were made to distribute radio tags over the duration of the run and in proportion to run strength by developing a deployment schedule based on fish wheel catches in previous years (Kerkvliet and Hamazaki 2002; Kerkvliet et al. 2003; Pawluk et al. 2006a, 2006b). Attempts were also made to tag fish in equal proportion along the north and south banks to ensure that all spatial components of the run had a non-zero probability of capture. Holding time in fish wheel live boxes has been shown to have an effect on fish recovery from the tagging procedure (J. Eiler, NOAA/NMFS, personal communication; Appendix 1.A), so efforts were made to limit holding time (time of capture though time of release) to less than one hour for all radiotagged sockeye salmon. Fish that were obviously injured, appeared excessively stressed, or were held more than one hour were not radiotagged.

In addition to an internal radio transmitter, all radiotagged fish were given a secondary mark of a uniquely numbered fluorescent colored anchor tag inserted near the dorsal fin (Guy et al. 1996). These anchor tags helped facilitate visual identification of radiotagged fish at the various recovery sites. Three scales were removed from the preferred region for age analyses (Devries and Frie 1996). Ages were later determined from scale patterns as described by Mosher (1969). A tissue sample from the axillary process was taken and stored in 100% ethanol for future genetic stock identification analyses. Information on sex, MEF length, condition of fish, and hold time were recorded. At the time of tagging, a record of each tag deployment was keyed into an electronic data logger including: the unique tag number, tag color, sex, MEF length, condition of fish, and holding time. Fish were released immediately after tagging.

In order to examine possible tag deployment biases, all captured sockeye salmon that did not receive the radio/anchor tag combination, were tagged with a single uniquely-numbered

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

fluorescent anchor tag inserted into the musculature just ventral to the dorsal fin (Guy et al. 1996). For fish that only received an anchor tag, the tag was color-coded to distinguish between fish tagged from the north and south bank fish wheel. The primary focus of this study relates to findings from the radio tag deployments; findings from anchor tag deployment are discussed in Appendix 1.B.

TAG RECOVERY AND TRACKING

Radiotagged sockeye salmon were tracked using both ground-based receiver stations and aerial tracking surveys. Seventeen ground-based stations were strategically distributed throughout the Kuskokwim River drainage, including the lower end of major spawning tributaries, and at escapement weirs (Figure 1.1). Each station consisted of several integrated components, including a computer-controlled ATS Model 4500 receiver and self-contained power system similar to Eiler (1995). Receivers were programmed to scan through frequencies at 6-second intervals. When a signal of sufficient strength was detected, the receiver paused for 12 seconds on each of two antennas (one oriented upstream and one downstream), and then the receiver recorded date and time the fish was present, signal strength, activity (active or inactive), and location of the fish relative to the station location (upstream or downstream). Receiver data were periodically downloaded to a laptop computer or transmitted to a NOAA geostationary operational environmental satellite (GOES) and downloaded via the internet.

Aerial tracking included coverage of the mainstem Kuskokwim River, major tributaries, and many smaller tributaries. The intention of the aerial tracking was to locate radiotagged fish that had not yet migrated into a spawning stream (including fates such as tag loss, handling mortality, or harvest); locate tagged fish in spawning tributaries other than those monitored with tracking stations; locate fish that ground-based stations failed to record; and validate records from the ground-based stations. Two drainagewide aerial tracking surveys were conducted each year, one in July and another in August, plus a third survey was conducted in early September that concentrated on the mainstem Kuskokwim and a few tributaries. The timing of aerial tracking events bracketed the period when most sockeye salmon were likely to be on spawning grounds based on previous tagging experience (Schaberg et al. 2010) and timing of sockeye salmon at tributary weir locations (e.g., Liller et al. 2008). Surveys were conducted in a fixed-winged aircraft flown at an altitude that ranged from 100 to 300 m above the ground surface, with one or two observers using ATS Model 4500 receivers. Two H- or Yagi antennas, each connected to a switching box, were mounted on the aircraft with one antenna placed on each wing strut. Antenna placement was such that the antennas detected peak signals perpendicular to the direction of travel. Dwell time on each transmitter frequency was one to two seconds. Once a tag was located, its frequency, code, and latitude/longitude were recorded by the receiver.

Radio and anchor tags were also recovered from fish captured in subsistence and sport fisheries. Recovered radio tags were re-deployed and voluntary tag recoveries were included in the stock-specific run timing analysis when applicable. To encourage tag returns, we conducted a postseason lottery each year. Each tag was printed with a toll-free number and address for reporting tag recoveries and for entering the lottery.

DATA ANALYSES

Findings from radio tag deployment were used to describe the distribution of sockeye salmon upstream of Kalskag, to describe stock-specific run timing past the tagging site, and to describe stock-specific migration rates. "Stock" as used here either refers to spawning aggregates from large tributaries sub-basins such as the Holitna River or smaller drainages within these sub-basins such as the Kogrukluk River. Though not a formal part of the study, we also explored the feasibility of estimating total inriver abundance of sockeye salmon using tag information (Appendix 1.B).

Distribution of radiotagged sockeye salmon was described by mapping the final destination as determined from both ground-based receiver stations and aerial tracking. "Final destination" was defined as the farthest upstream location reported for a radiotagged fish within any tributary of the Kuskokwim River. In an attempt to best reflect the expected distribution of spawning sockeye salmon, only radiotagged fish tracked to a tributary stream were included in the final analysis. There is no evidence of sockeye salmon spawning in the mainstem Kuskokwim River. Tagged fish that were detected in the mainstem Kuskokwim River are believed to represent a combination of regurgitated tags and fish that expired prior to entering a tributary system. Fish that did not resume upstream migration (defined as passing the first upstream ground-based receiver station at Birch Tree Crossing, rkm 294; Figure 1.1) were also excluded in an effort to mitigate bias related to tagging and handling stress. The proportion of radiotagged sockeye salmon that returned to a particular tributary was calculated with adjustments to account for changes in the daily radiotagging rate and fishing effort (Wuttig and Evenson 2002). The weighted proportion for an individual spawning stock was calculated as:

$$\hat{P}^{*}{}_{Stock_i} = \frac{\sum_{i=1}^{n_t} w_i I(Stock_i)}{\sum_{i=1}^{n_t} wi} \qquad (1)$$

where:

$$w_i = \left(\frac{X_i}{h_i x_i}\right) \qquad (2)$$

$I(Stock_i)$ = 1 if fish i was assigned to stock i and 0 otherwise

X_i = the number of fish captured on day i;

x_i = the number of fish radiotagged on day i;

h_i = the hours of fishing effort on day i; and

n_t = the total number of radiotagged fish.

The variance and 95% confidence intervals of $\hat{P}^{*}{}_{Stock_i}$ were estimated using parameterized bootstrap techniques (Sokal and Rohlf 1995). Using Equation (1), 2,000 bootstrap estimates were computed after drawing samples of size equal to the number of radiotagged fish with replacement from the original data that was comprised of a list of fates of all the radiotagged fish. The sample variance of these bootstrap replicates was used to estimate Var($\hat{P}^{*}{}_{Stock_i}$). The 2.5 and 97.5 percentiles of the bootstrap distribution were used to estimate a 95% CI.

Stock-specific run timing at the tagging site were described through examination of the tagging date for each radiotagged salmon that successfully reached a spawning area (Mundy 1979; Merritt and Roberson 1986; Keefer et al. 2004). The median date of passage for each stock was calculated. Differences in run timing among major stocks were tested using Kolmogorov-Smirnov tests (Sokal and Rohlf 1995).

Stock-specific migration rates upstream of the tagging site were determined through examination of the number of days it took radiotagged fish to travel between the ground-based receiver station at Birch Tree Crossing and a ground-based receiver station near the mouth of one of three sub-basins including the Stony (and outlet of Telaquana Lake), Holitna (and Hoholitna and Kogrukluk), and Aniak rivers (Figure 1.1). Migration rate was defined as the average river kilometers per day between towers. Additionally, migration rates of radiotagged fish returning to the Holitna and Stony rivers were compared over a standardized section of the Kuskokwim River from the Birch Tree Crossing receiver station (rkm 294) to the Red Devil station (rkm 472). Differences were compared using t-tests (Sokal and Rohlf 1995).

RESULTS

TAGGING

The temporal distribution of deployed radio tags was a few days earlier than the overall sockeye salmon run timing, as estimated by catches in the fish wheels both in 2006 and 2007 (Figure 1.2). In 2006, 498 radio tags were deployed, the first on 14 June and the last on 15 August, with 50% deployed in fish captured on the north bank and 50% on the south bank. In 2007, 488 radio tags were deployed, the first on 21 June and the last on 14 August, with 48% deployed on the north bank and 50% on the south bank (2% had incomplete information records). The proportion of tags recovered by bank of capture was similar for all monitored stocks except the Aniak River. In 2006, 70% of fish tracked to the Aniak River were tagged on the south bank; and in 2007, 60% were tagged on the south bank.

Fates were described for all radiotagged fish (Table 1.1). In both 2006 and 2007, 3% of radiotagged fish either lost their tags or were never located after tagging. In 2006, 9% of radiotagged fish were detected downstream of the tagging site and did not resume upstream migration, compared to 15% in 2007. Among the successful upstream migrants (defined as migrating past the first upstream tracking station at Birch Tree Crossing), 88% were tracked to a spawning tributary in 2006, and 83% in 2007.

Age, sex, and length composition of the radiotagged fish was similar in 2006 and 2007 (Table 1.2). No 0-check fish were among those radiotagged in 2006, but four were found among the 2007 deployments (0-check fish undergo smoltification within a few months after emergence from the gravel, so their scales have no freshwater annulus or “check”).

DISTRIBUTION

Radiotagged sockeye salmon primarily traveled to tributaries within the middle Kuskokwim River basin (Figures 1.3, 1.4). Based on weighted distributions, Holitna River sub-basin accounted for the majority of the radiotagged fish in both years, followed by Stony River sub-basin and the Aniak River sub-basin (Tables 1.3, 1.4). Smaller numbers of fish were tracked to the Holokuk, Oskawalik, and George rivers. In 2006, one radiotagged fish was found in Vreeland Creek and one in Swift River drainage. No radiotagged sockeye salmon were found in the Kuskokwim River basin upstream of the Swift River drainage in either year.

The majority of radiotagged fish were located in areas of sub-basins without access to lakes. Within the Holitna River sub-basin, radiotagged fish were tracked to both the mainstem Holitna River and various tributaries (Tables 1.3, 1.4). The majority were tracked to the mainstem Holitna River, but a notable number of tagged fish were located in the larger tributaries, specifically the Hoholitna, Kogrukluk, and Chukowan rivers. No radiotagged fish entered Whitefish Lake at the headwaters of the Hoholitna River. Within the Stony River sub-basin, radiotagged fish were tracked to locations in either mainstem Stony River or one of two lake systems (Telaquana Lake and Two Lakes). Within the Aniak River sub-basin, radiotagged fish were found in both the mainstem Aniak River and various tributaries; however, the majority were tracked to the mainstem Aniak River downstream of the confluence with the Salmon and Kipchuk rivers. No radiotagged sockeye salmon were tracked to Aniak Lake.

STOCK-SPECIFIC RUN TIMING

The timing of stocks passing the Kalskag tagging site followed similar trends in 2006 and 2007 (Figure 1.5). The median date of passage for Stony River radiotagged fish was 3 July in 2006 and 2 July in 2007. The median date of passage for fish tracked to the Holitna River sub-basin was 5 July in 2006 and 7 July in 2007 and for fish tracked to the Aniak River the median dates of passage were 13 July in 2006 and 8 July in 2007. In 2006, there was a significant difference in run timing between fish tracked to the Stony and Aniak rivers ($D=0.339$, $P<0.01$) and between fish tracked to the Holitna and Aniak rivers ($D=0.250$, $P<0.05$), but not between fish tracked to the Stony and Holitna rivers ($D=0.178$, $P=0.075$). In 2007 there was a significant difference in run timing between fish tracked to the Stony and Aniak rivers ($D=0.539$, $P<0.001$) and between fish tracked to the Stony and Holitna rivers ($D=0.372$, $P<0.001$), but not between fish tracked to the Holitna and Aniak rivers ($D=0.167$, $P=0.478$).

STOCK-SPECIFIC MIGRATION RATES

Radiotagged sockeye salmon returning to the Holitna River basin generally traveled the fastest on average from the Birch Tree Crossing start point to the ground-based receiver in the lower Holitna River basin (Table 1.5; Appendix 1.C). Aniak River fish traveled slowest from the Birch Tree Crossing start point in both years. Radiotagged fish returning to the Stony River drainage traveled slower than Holitna River fish in both years. Though they had the longest migration distance, radiotagged fish returning to Telaquana Lake traveled slower than Holitna fish in both years. Travel rates indicate that radiotagged fish tended to travel faster in the mainstem Kuskokwim River than within tributaries.

Similar relationships were found for migration rates of Holitna River and Stony River fish from the Birch Tree Crossing tracking station to the Red Devil station. Over this stretch of mainstem, fish tracked to the Holitna River traveled at an average rate of 48.7 rkm/day in 2006, and 41.3 rkm/day in 2007, and Stony River fish traveled at 43.1 rkm/day and 40.8 rkm/day. There was a significant difference between migration rates in 2006 ($t=2.56$, $df=318$, $P<0.05$), but not 2007.

DISCUSSION

TAGGING

The number of radiotagged fish found downstream of the tagging site, and did not resume upstream migration after tagging, was less in 2006 than in 2007. In both years, similar efforts were made to reduce holding time to minimize stress on the fish. It is possible that different water conditions between the two years resulted in fish being less stressed in 2006 than in 2007. Temperatures have been shown to lead to increased pre-spawning loss and stress in the Fraser River (IPSFC 1976; Crossin et al. 2008), but average surface water temperatures at the Kuskokwim tagging site were nearly identical between the two years during June and early July. There was, however, lower water levels and increased water clarity in June and July of 2007 that may have increased stress (http://waterdata.usgs.gov/usa/nwis/nwisman/?site_no=15304000&agency_cd=USGS). Difference between the two years could also be due to variability in the effectiveness of the crew at successful implanting the radio transmitters.

DISTRIBUTION

Significance of Holitna River Drainage

The Holitna River drainage appears to be the primary destination of returning sockeye salmon in the Kuskokwim River, accounting for 71% and 70% of the weighted tributary tag distribution upstream of Kalskag in 2006 and 2007, respectively. Sockeye salmon occur in tributaries downstream of the study area (Tuluksak, Kisaralik-Kasigluk, Kwethluk, and Eek rivers), but abundance in each of these streams appears limited, ranging from few dozen to a few thousand fish based on weir counts in the Tuluksak and Kwethluk rivers (Molyneaux and Brannian 2006). The prominence of sockeye salmon in the Holitna River echoes similar findings for Chinook (Stuby 2007) and chum salmon (Bue et al. 2008), and highlights the importance of this sub-basin to overall salmon production in the Kuskokwim River.

The importance of the Holitna River to the overall Kuskokwim River sockeye salmon run supports the utility of managers using the Kogrukluk River weir, located in the upper Holitna River drainage, as an index site for monitoring sockeye salmon escapement. The Kogrukluk River accounted for 15 and 17% of the total distribution in this study, and has an average annual escapement of 12,744 sockeye salmon (range 1,670–60,807; Molyneaux and Brannian 2006). A minimum escapement goal of 2,000 sockeye salmon was established for the weir in 1983 (Buklis 1993), but the goal was discontinued in 1993. This decision was made under the assumption that sockeye salmon were incidental in the Kogrukluk River, and Holitna River generally, because of the lack of lake habitat in the drainage that is typically associated with sockeye salmon. So, the logic went, these drainages were assumed to not be representative of the bulk of Kuskokwim River sockeye salmon production (Burkey et al. 1999). In light of our findings, however, the Kogrukluk River may indeed be a reasonable index stream for monitoring sockeye salmon escapement, and in 2009 ADF&G re-established an escapement goal at the weir of 4,400–17,000 as part of a response to growing interest in developing a directed commercial sockeye salmon fishery (Volk et al. 2009).

Life History Strategies

Sockeye salmon are typically associated with rivers that provide access to lake habitat where juveniles rear for one to two years prior to smolting, such as those found in Bristol Bay (Burgner 1991). These are referred to as following a "lake ecotype" life history strategy (Wood et al. 2008). Likely lake-type populations within our study area include fish from the Stony and Holokuk rivers, which only accounted for 18 to 20% of radiotagged fish in 2006 and 2007. Downstream of our study area, lake-type populations have also been reported in the Kwethluk River (McPhee et al. 2009).

Tributaries with no associated lake system accounted for 81% and 78% of the total tributary tag distribution in our study area in 2006 and 2007, respectively, including fish from the Holitna, Aniak, Oskawalik, and George rivers. Sockeye salmon from these streams appear to follow the "river ecotype" life history strategy where following emergence juveniles rear and overwinter in river channel and slough habitats where water velocity is slow (Wood et al. 2008). River-type populations are not abundant across the Pacific Rim, though small populations are reported throughout much of the species range (e.g. Wood et al. 1987; Burgner 1991; Gustavson and Winans 1999; Eiler et al. 1992). A relatively large population of river-type sockeye salmon in the Kuskokwim River was unexpected because of the presence of predatory northern pike (*Esox lucius*) and sheefish (*Stenodus leucichthys*), and large populations of Chinook and coho (*O. kisutch*) salmon with piscivorous juvenile stages (Chapter 2 this document).

Some watersheds also produce 0-check or "sea ecotype" sockeye salmon that spend at most a few months after emergence in river habitats before smolting (Wood et al. 2008). Examples of watersheds with more prominent sea-type sockeye salmon include Harrison River (Fraser watershed), Stikine River, Puget Sound rivers, and Nushagak River (Schaefer 1951; Wood et al. 1987; Gustafson and Winans 1999; Westing et al. 2005). However, no 0-checked fish were among those radiotagged in the Kuskokwim River in 2006, and the incidence in 2007 was <1%. Similarly, 0-check sockeye salmon account for <1% of the historical commercial harvest in the Kuskokwim River (Molyneaux and Folletti 2005).

These three life history strategies likely reflect differences in productivity. This has been demonstrated by differences in sizes, ages, and fecundities of spawning adults (Rogers 1987; Blair et al. 1993), in high heterogeneity in sizes of riverine juveniles (Wood et al. 1987), and differences in genetic diversity and genetic structure (Beacham et al. 2004; Gustafson and Winans 1999; McPhee et al. 2009). Interestingly, there was a difference in the proportion of radiotagged sockeye salmon returning to the Stony River between 2006 and 2007, a trend not observed in any of the river-type populations. This could reflect different dynamics encountered by lake-type versus river-type life histories. River-type sockeye salmon may return to dynamic spawning areas more susceptible to changes in water level, freezing, dessication, or silt load, but may also be more able to move to more suitable spawning habitats. Lake-type populations may have more stable habitats in some years, but populations may be less able to adapt to changing environments. One life history type might be a greater producer under one climatic scheme, while the other could dominate under a different climatic regime. This biocomplexity is important for maintaining the resilience of the species under environmental change (Hilborn et al. 2003; Schindler et al. 2010). Genetic stock identification techniques applied to mixed-stock samples, such as commercial harvest, may prove to be a useful and cost effective tool for assessing short-term and long-term shifts between river-type and lake-type sockeye salmon in the Kuskokwim River.

Kuskokwim River salmon managers cannot necessarily apply knowledge gained elsewhere from lake-type sockeye salmon populations as they may not be truly representative of productivity. River-type populations may have higher volatility in their annual abundance compared to lake-type populations, probably associated with instability in their riverine spawning and rearing environments (McPhee et al. 2009). Consequently, a fishery reliant on river-type sockeye salmon should expect more variable annual harvest levels than occur in fisheries focused on lake-type fish. This high volatility is evident in the coefficient of variations (CVs) of annual sockeye salmon escapements at weir projects in the Kuskokwim River. Among example river-type populations, CVs include 1.17 at Takotna River, 0.95 at Tatlawiksuk River, 0.95 at Kogrukluk River, 0.89 at George River, and 0.89 at Tuluksak River. In comparison, the CV is only 0.62 in the Middle Fork Goodnews River and 0.67 in the Kanektok River where lake-type fish dominate. Interestingly, the CV for Kwethluk River abundance is 0.67, which may indicate that lake-type fish are more prevalent than river-type fish. These calculations were limited to escapements occurring between 2001 and 2008, when minimal commercial harvest occurred in the Kuskokwim River, and a relatively consistent harvest occurred in Kuskokwim Bay where Middle Fork Goodnews and Kanektok river fish are harvested. Given this volatility, and the limited capacity for real-time assessment of sockeye salmon abundance in the Kuskokwim River, an aggressive harvest strategy dependent on river-type sockeye salmon has a higher risk of overexploitation. The likely variability in productivity between river-type and lake-type populations requires monitoring escapements of both life history types.

Possible Colonization

No radiotagged fish traveled upstream of the Swift River drainage; however, occurrence of small numbers of sockeye salmon are documented in a few upper Kuskokwim River tributaries, notably the Takotna (Costello et al. 2008), Tatlawiksuk (Stewart et al. 2008), and South Fork Kuskokwim (Nick Alexia, resident, Nikolai, personal communication) rivers. In the Takotna River, which has annual escapement estimates since 2000, sockeye salmon passage has ranged from 0 to 60 fish. It is possible that these fish are strays from river-type Kuskokwim sockeye salmon stocks, considering Wood et al. (2008) argument that river-type sockeye salmon are more likely to stray from natal streams and colonize new habitats. Lake-type populations are less likely to stray, though this hypothesis has been challenged in at least some instances (e.g., Pavey et al. 2007). Studies suggest that riverine sockeye salmon may have been the primary colonists of new habitat following glaciation (Wood 1995). Also, genetics studies demonstrate less differentiation among river-type sockeye salmon populations compared to lake-type populations, implying that natal homing may be less precise in river-type populations (Gustafson and Winans 1999; Beacham et al. 2004). Recent studies confirm this relationship amongst some Kuskokwim River sockeye salmon populations (McPhee et al. 2009)

Stock-Specific Run Timing

There was broad overlap in run timings at the tagging site between Holitna, Stony, and Aniak River sockeye salmon stocks, which collectively comprise about 95% of the run. Consequently, it is unlikely that managers could time the harvest to target one of these major stocks over another. This same pattern of broad overlap in run timing is consistent with the pattern seen with anchor tags in 2002 through 2006 (Appendix 1.C; Schaberg et al. 2010).

Stock-specific run timing patterns may have limited management function for Kuskokwim River sockeye salmon, but studies focused on other species at times showed a wide divergence between stocks that does hold potential for management application, particularly for chum salmon (Schaberg et al. 2010). Regardless of species, in question is whether the stock-specific run timing patterns seen at the Kalskag tagging site (rkm 270) can be extrapolated downstream to District 1 (rkm 5 to 203) where most of the harvest occurs. There were practical reasons why tagging was done near Kalskag instead of in District 1, including concern for loss of expensive radio tags to District 1 harvest, and the need for adequate river current to operate fish wheels that allowed catching large numbers of fish for tagging. Still, to resolve the issue, concurrent tagging in District 1 and the Kalskag site should be conducted while the wide geographic array of tag recovery platforms (weirs) still exists. Such a study would also clarify how lower Kuskokwim River salmon stocks such as those in the Kwethluk and Tuluksak rivers place in the run timing patterns.

Stock-Specific Migration Rates

Average migration rates in the mainstem Kuskokwim River varied widely between stocks, ranging from about 9 to 30 rkm/day for Aniak and Holitna River sockeye salmon. Slower migrating stocks could be more susceptible to harvest because of their protracted exposure to the fishery. Results from this study indicate that while there may be some differences in migration rates between stocks, it is likely that the run timings of specific stocks overlap throughout the migration route. As with stock-specific run timing, it is unknown whether the stock-specific migration rates seen at the Kalskag tagging site (rkm 270) can be extrapolated downstream to District 1 (rkm 5–203). Again, concurrent tagging in District 1 and the Kalskag site would provide some resolution.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study should be taken in context, since the behavior and distribution of tagged fish may or may not be representative of untagged fish. It is possible that some stock selectivity existed in the design of this study, though there was no way to measure this bias with the existing platform. Efforts to recover anchortagged fish in 2006 allowed a means to test for potential biases in that year, and results suggest equal probability of capture between Telaquana Lake and Kogrukluk River weir capture sites (Appendix 1.B). These efforts lend support to the distributions seen here, but are only one year of limited diagnostics. Further study is necessary in order to assess the applicability of the results cited here, and caution should be used when interpreting these results.

However, this study was the first to document sockeye salmon distribution in the Kuskokwim River drainage. Several points were learned from this study that could be important for management:

1. Both river-type and lake-type sockeye salmon life history ecotypes are important contributors to the annual Kuskokwim River sockeye salmon run, though river-type may be the more dominant.
2. The Holitna River basin had the single largest concentration of radiotagged sockeye salmon in the Kuskokwim River, with the Stony and Aniak River basins being the second and third largest concentrations, respectively.
3. Stock-specific run timing and migration rates at Kalskag show broad overlap between stocks.
4. The Kogrukluk River weir provides a reasonable index for monitoring sockeye salmon escapement to the Kuskokwim River. Long-term operations of this weir are necessary to assess the adequacy of the escapement within the context of the escapement goal range of 4,400–17,000 sockeye salmon, established in 2009.
5. Future measures should include establishing an escapement monitoring program representative of the diversity found within Kuskokwim River sockeye salmon. Establishing such a platform would also provide the means to develop a total abundance estimate that will be needed to address issues of harvestable surplus, exploitation rate, and annual variability in stock composition. In addition, this platform would be necessary for the diagnostics necessary for mark–recapture models and to verify the validity of the distributions presented in this study.

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TABLES AND FIGURES

Table 1.1.–Fates of Kuskokwim River sockeye salmon radiotagged at the Kalskag Fish Wheels in 2006 and 2007.

Fate	Description	Number of tagged sockeye 2006	Number of tagged sockeye 2007	Percent of tagged sockeye 2006	Percent of tagged sockeye 2007
Not Detected	A fish that was never recorded swimming upstream past the Birch Tree Crossing tracking site (rkm 294).	17	17	3	3
Downstream	A fish that was detected downstream of the Kalskag tagging site that did not resume upstream migration.	44	71	9	15
Upstream Migrant	A fish that migrated upstream past the Birch Tree Crossing tracking site (rkm 294).	437	400	88	82
Tributary Spawner	A fish that entered a spawning tributary of the Kuskokwim River.	383	333	77	68
Subsistence Mortality	A fish that was reported as harvested by subsistence fishers.	3	3	1	1
	Total Deployed	498	488		

Table 1.2.–Age and sex composition of radiotagged sockeye salmon in 2006 and 2007.

Age	2006								2007							
	Females		Males		Unknown		Total		Females		Males		Unknown		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0.3	0	0.0	0	0.0	0	-	0	0.0	2	1.1	2	0.8	0	0.0	4	0.9
1.2	22	12.0	16	6.4	0	-	38	8.8	22	12.5	44	18.0	1	50.0	67	15.9
1.3	137	74.5	206	82.7	0	-	343	79.2	133	75.6	169	69.3	1	50.0	303	71.8
1.4	16	8.7	15	6.0	0	-	31	7.2	9	5.1	16	6.6	0	0.0	25	5.9
2.2	0	0.0	3	1.2	0	-	3	0.7	1	0.6	0	0.0	0	0.0	1	0.2
2.3	9	4.9	7	2.8	0	-	16	3.7	9	5.1	13	5.3	0	0.0	22	5.2
2.4	0	0.0	2	0.8	0	-	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0
ND	18		44		3		65		17		47		2		66	
Total Aged	184		249	50	0	0	433		176		244		2		422	
Total Sampled	202	40.6	293	58.8	3	0.6	498		193	39.5	291	59.6	4	0.8	488	

Note: Percentage by age is based on the number of aged scales. Percent by sex is based on total number of sockeye salmon sampled.

Table 1.3.–Distribution of radiotagged sockeye salmon in spawning tributaries of the Kuskokwim River in 2006, with adjustment to account for differences in daily tagging rates and fishing efforts.

Spawning Stream		Number of radio tags		Proportion of all radio tags[a]		Percentile Limits (5th - 95th)	
Tributary	Sub-basin	Tributary	Sub-basin	Tributary	Sub-basin	Tributary	Sub-basin
Aniak - ALL		36		0.09		(0.01, 0.18)	
	Mainstem		21		0.06		(0.00, 0.13)
	Kipchuk		4		0.01		(0.00, 0.02)
	Upper Aniak		11		0.03		(0.00, 0.07)
Holokuk		12		0.03		(0.00, 0.10)	
Oskawalik		5		0.01		(0.00, 0.03)	
George		2		0.00		(0.00. 0.00)	
Holitna - ALL		264		0.71		(0.21, 1.00)	
	Mainstem		118		0.34		(0.07, 0.60)
	Hoholitna		54		0.15		(0.02, 0.29)
	Chukowan		27		0.07		(0.00, 0.16)
	Kogrukluk		61		0.15		(0.01, 0.28)
	Other		4		0.01		(0.00, 0.04)
Stony - ALL		62		0.15		(0.00, 0.32)	
	Mainstem		21		0.05		(0.00, 0.13)
	Telaquana		23		0.06		(0.00, 0.15)
	Two Lakes		18		0.03		(0.00, 0.08)
Other		2		0.01		(0.00, 0.01)	
TOTAL		383		1.00			

[a] Adjusted for daily tagging rates and fishing effort.

Table 1.4.–Distribution of radiotagged sockeye salmon in spawning tributaries of the Kuskokwim River in 2007, with adjustment to account for differences in daily tagging rates and fishing efforts.

Spawning Stream		Number of radio tags		Proportion of all radio tags[a]		Percentile Limits (5^{th} - 95^{th})	
Tributary	Sub-basin	Tributary	Sub-basin	Tributary	Sub-basin	Tributary	Sub-basin
Aniak - ALL		27		0.08		(0.04, 0.13)	
	Mainstem		14		0.04		(0.02, 0.06)
	Kipchuk		4		0.01		(0.00, 0.02)
	Upper Aniak		9		0.03		(0.00, 0.06)
Holokuk		7		0.01		(0.00, 0.03)	
Oskawalik		1		0.00		(0.00, 0.01)	
George		1		0.00		(0.00, 0.00)	
Holitna - ALL		222		0.70		(0.41, 1.00)	
	Mainstem		81		0.25		(0.15, 0.36)
	Hoholitna		63		0.21		(0.11, 0.30)
	Chukowan		24		0.06		(0.03, 0.10)
	Kogrukluk		53		0.17		(0.07, 0.28)
	Other		2		0.01		(0.00, 0.02)
Stony - ALL		75		0.19		(0.11, 0.27)	
	Mainstem		29		0.05		(0.02, 0.08)
	Telaquana		18		0.06		(0.02, 0.09)
	Two Lakes		28		0.08		(0.04, 0.13)
Other		0		0.00		(0.00, 0.00)	
TOTAL		333		1.00			

[a] Adjusted for daily tagging rates and fishing effort.

Table 1.5.–Migration rates (rkm/day) of radiotagged sockeye salmon in 2006 and 2007, based on ground-based tracking stations.

		2006			2007		
Tracking Station	Distance from Birch Tree Crossing tracking station (rkm)	Mean	95% CI	N	Mean	95% CI	N
Aniak River	29	6.7	0.9	36	5.2	0.9	27
Holitna River	204	27.4	0.9	264	23.6	0.8	222
Hoholitna River	252	28.0	2.2	54	25.0	1.4	63
Kogrukluk River	416	22.0	1.7	61	19.5	1.4	53
Stony River	249	21.2	1.4	62	20.5	1.4	75
Telaquana Lake	462	17.7	2.1	21	19.4	1.8	18

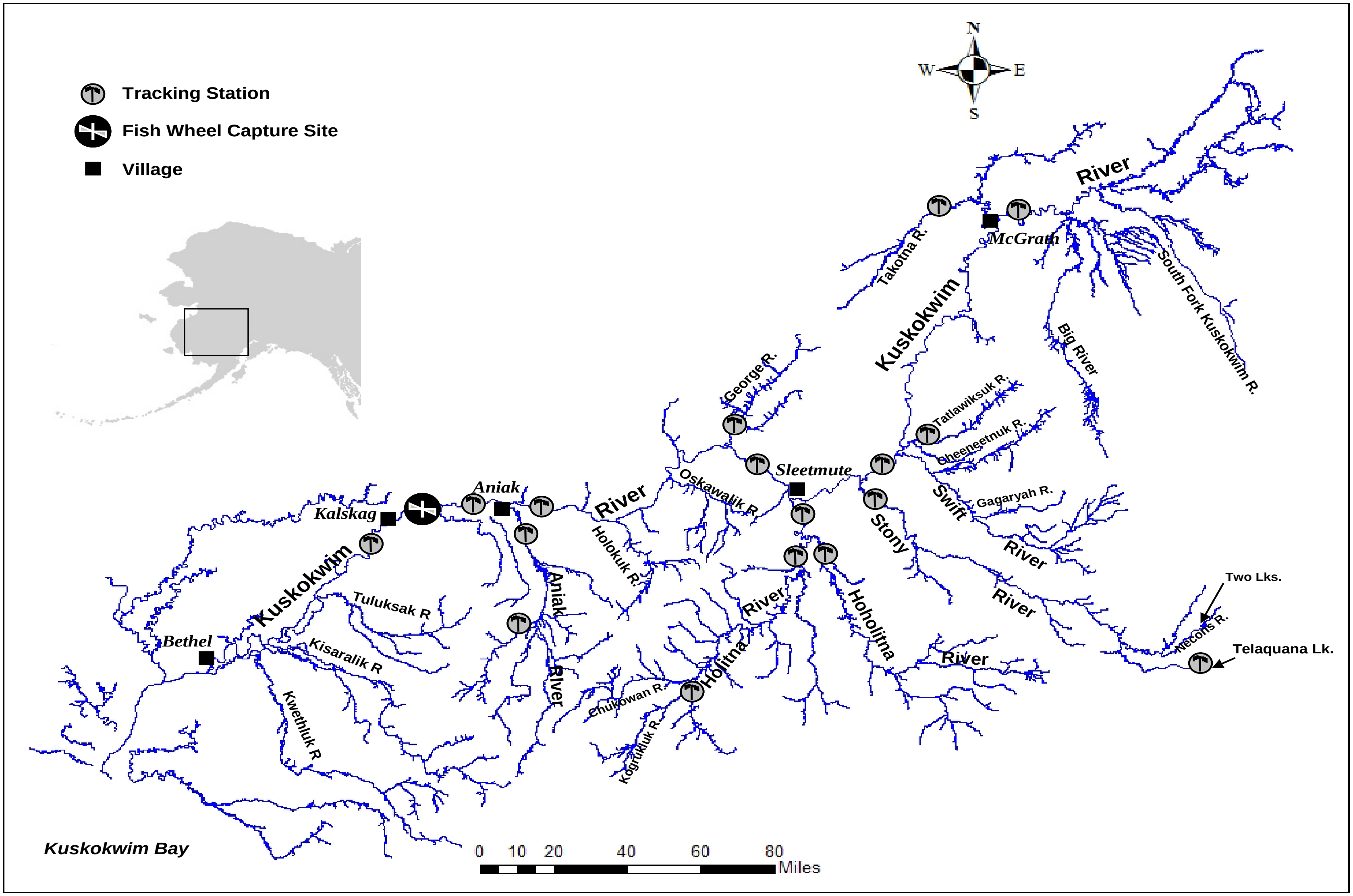

Figure 1.1.–Map of the Kuskokwim River showing tributaries, capture sites, and ground-based tracking stations.

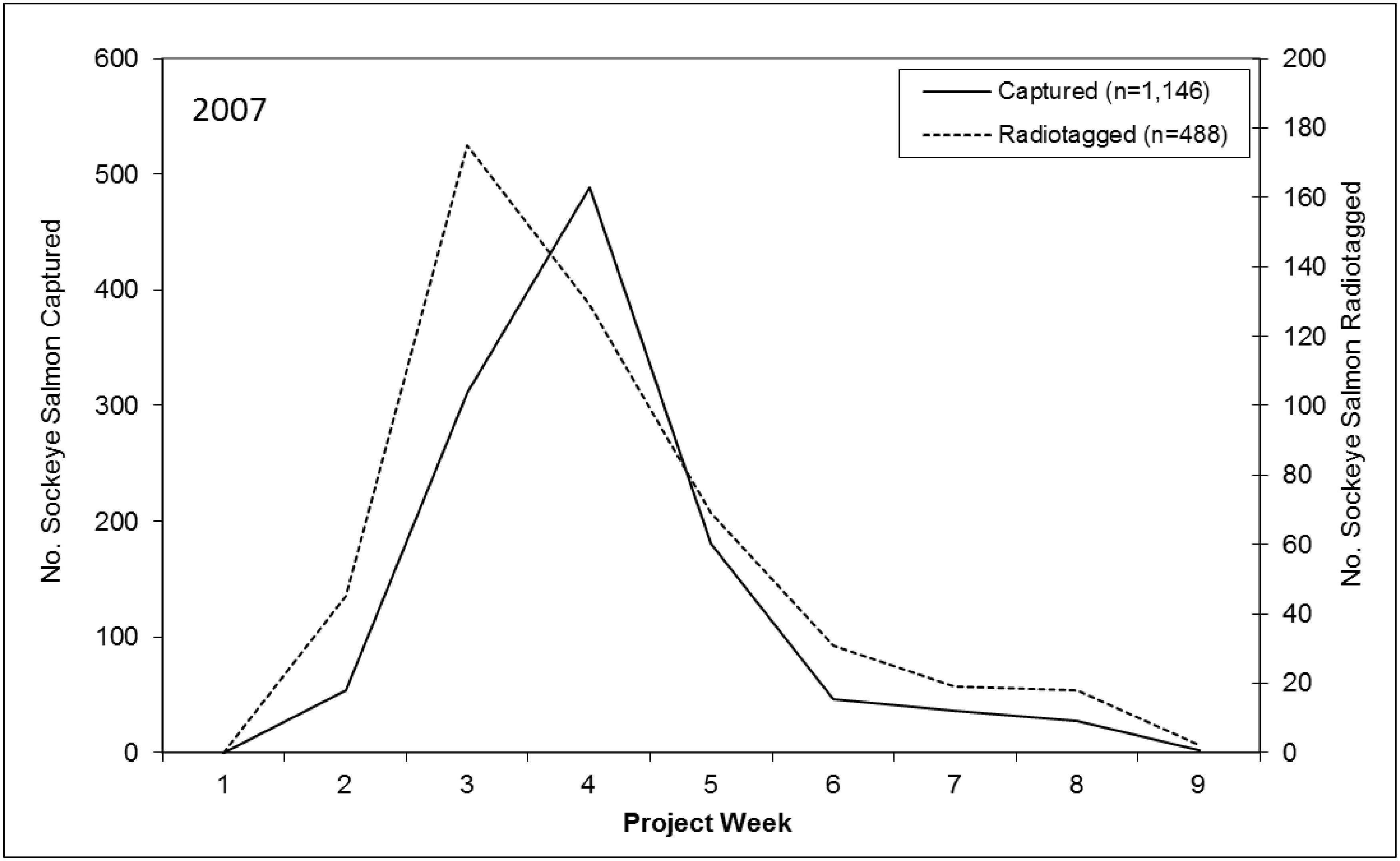

Figure 1.2.–Number of sockeye salmon captured and radiotagged by project week in 2006 and 2007.

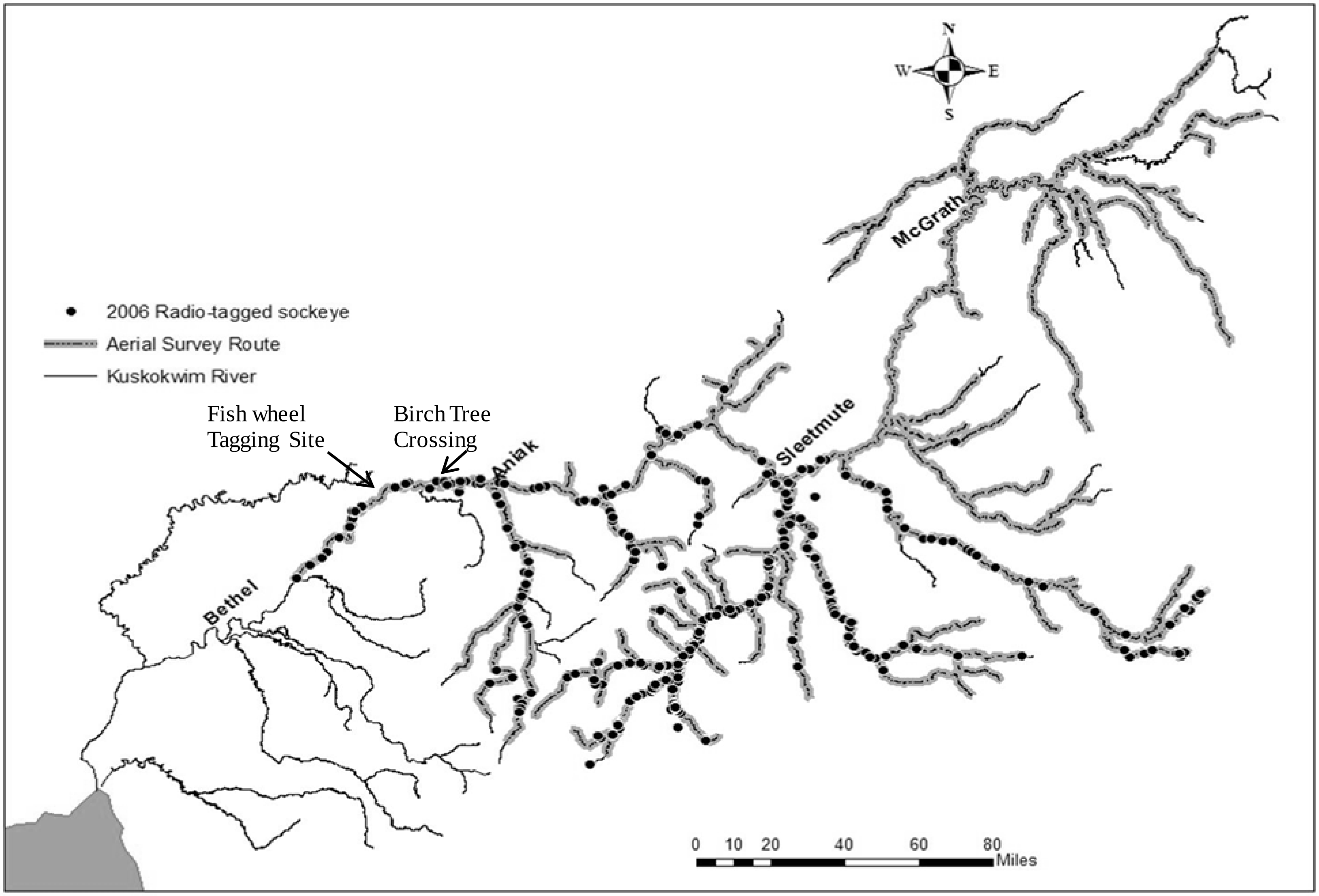

Figure 1.3.–Kuskokwim River drainage with aerial tracking coverage and uppermost locations of radiotagged sockeye salmon in 2006.

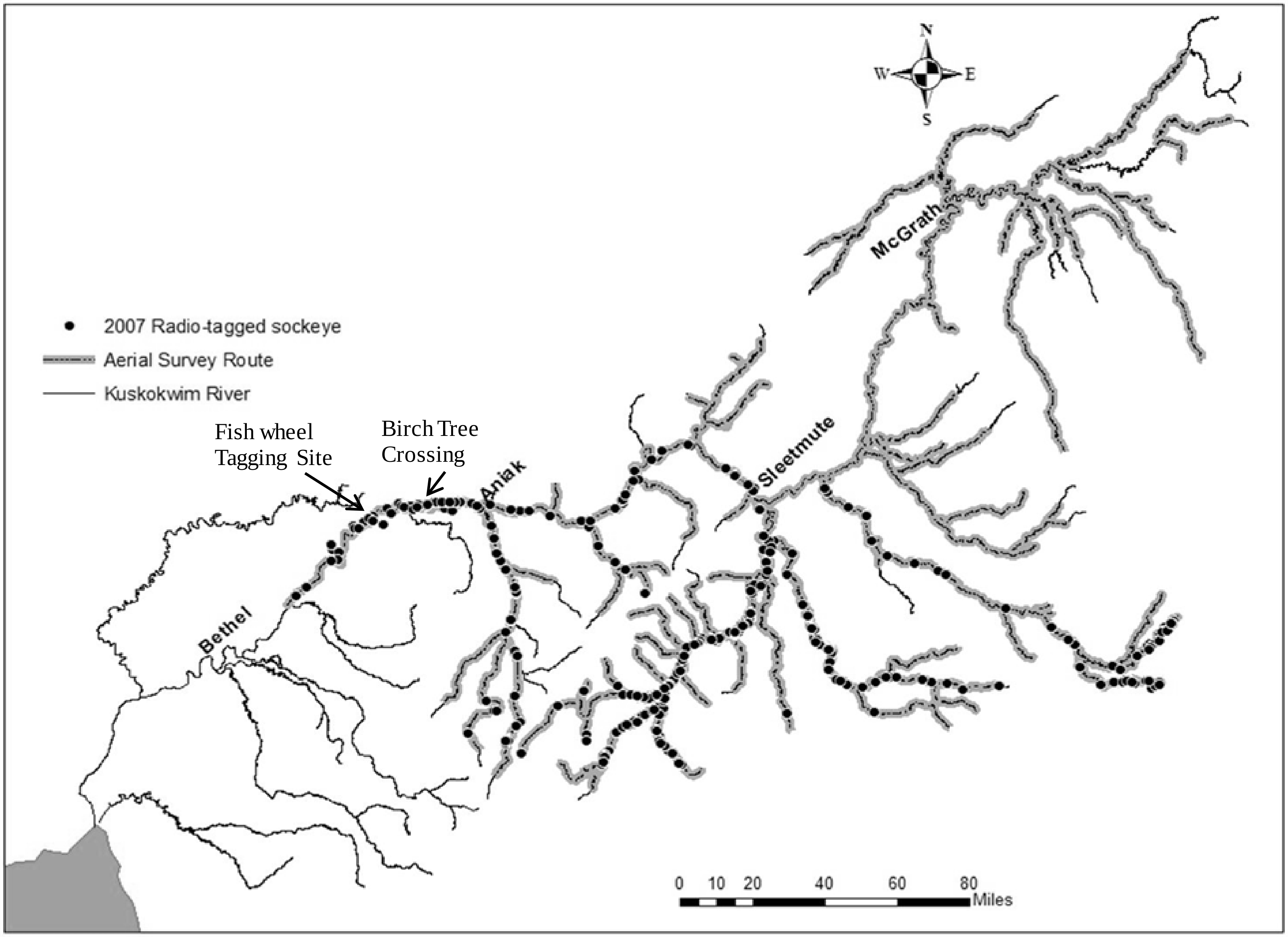

Figure 1.4.–Kuskokwim River drainage with aerial tracking coverage and uppermost locations of radiotagged sockeye salmon in 2007.

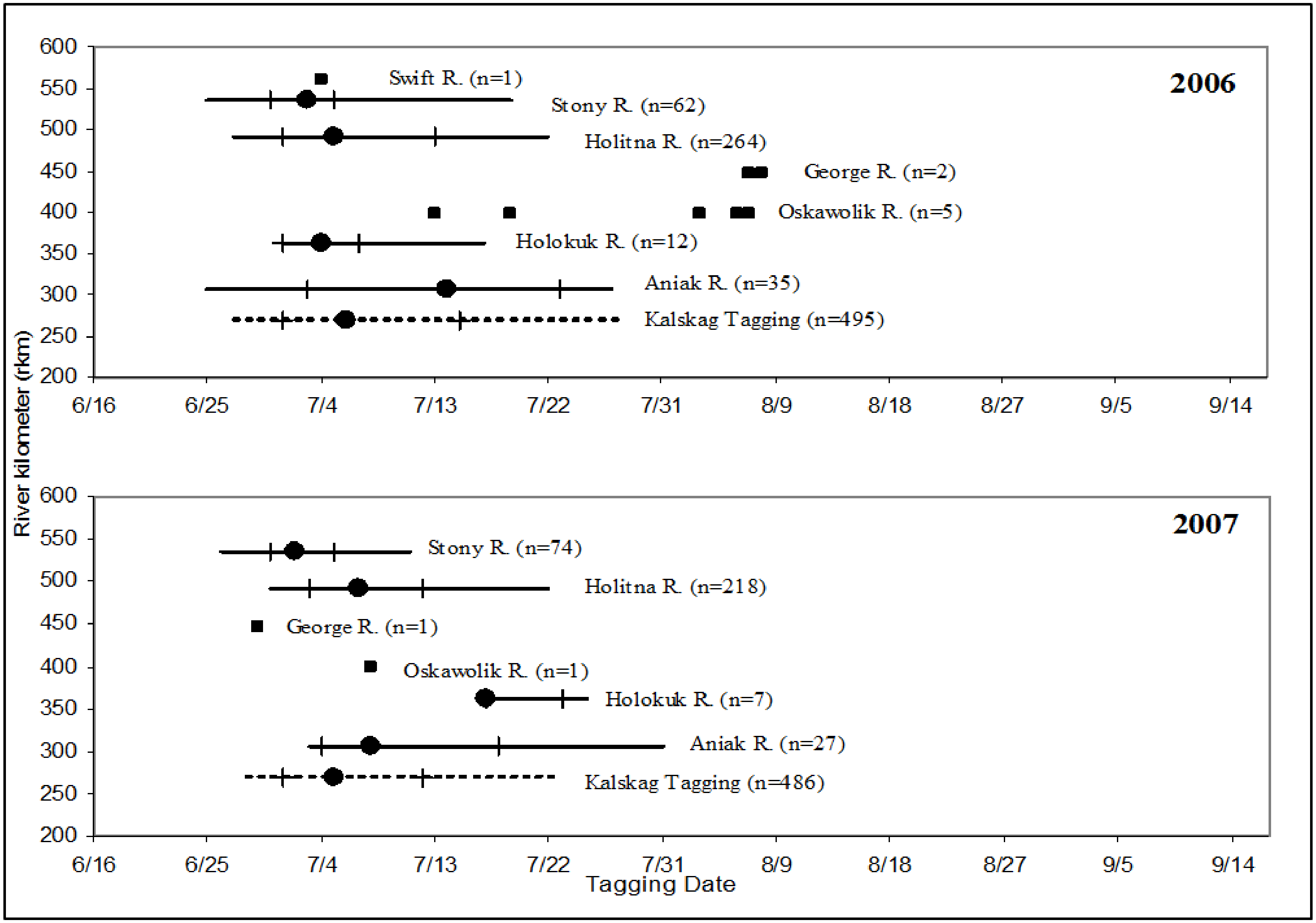

Figure 1.5.–Stock-specific run timing for sockeye salmon radiotagged in 2006 and 2007, including median (circle), quartile (vertical lines), and 10th and 90th percentile dates (horizontal line). Squares are tagging date for individual fish in tributaries with <5 recovered tags.

APPENDIX 1.A: 2005 PILOT RADIOTAGGING STUDY

Introduction

A pilot radiotelemetry project was conducted on Kuskokwim River sockeye salmon in 2005, as a precursor to the 2006–2007 efforts. Using funds provided by Coastal Villages Region Fund, National Park Service, and ADF&G, we purchased radio tags and tower supplies to study the feasibility of a full-scale radiotelemetry project. Results included some unexpected insights that were important in designing the 2006–2007 investigation.

Objectives:

1. Investigate geographic distribution of sockeye salmon spawning areas within the Kuskokwim River drainage upstream of Kalskag,
2. Investigate stock-specific run timing of adult sockeye salmon as they pass upstream of the Kalskag tagging site,
3. Identify and address potential difficulties associated with basinwide sockeye salmon radiotelemetry, and
4. Provide sockeye salmon tissue samples to identify discreet spawning populations through genetic analysis.

Methods

Capture and Tagging

Adult sockeye salmon returning to the Kuskokwim River in 2005 were captured with fish wheels at sites near the village of Upper Kalskag (Figure A1.1). Tags were deployed from 24 June to 1 July in order to correspond with the peak of sockeye salmon passage. The tagging event was partitioned into three tagging periods (Table A1.1). Efforts during the first period focused on evaluating the effects of tag size and holding time. During the second and third periods holding time was held to less than one hour to minimize tagging effects on fish behavior.

Fish were tagged with pulse-coded esophageal radio transmitters manufactured by Advanced Telemetry Systems (Isanti, Minnesota). Three tag models were used to evaluate effects of tag size: model F1835 (17 x 42 mm), model F1840 (17 x 51 mm), and model F1845 (19 x 51 mm). The size of the tag varied according to battery size, with a larger battery expected to result in a longer tag life. To best evaluate the effects of tag sizes, smaller fish (<550 mm MEF length) were initially targeted to be tagged with model F1845 tags and larger fish (>600 mm MEF length) were targeted to be tagged with model F1835 tags. Tagging was conducted without the use of anesthesia. Fish that were obviously injured or appeared stressed were not radiotagged. Transmitters were individually distinguishable by a unique encoded pulse pattern and frequency. Two frequencies with 50 encoded pulse patterns per frequency were used for a total of 100 uniquely identifiable tags.

All radiotagged fish were given a secondary mark of a uniquely numbered white spaghetti tag inserted near the dorsal fin (Guy et al. 1996). Information on sex, mideye to fork of tail (MEF) length, and hold time were recorded. Three scales were removed from the preferred region for age analyses (Devries and Frie 1996). A tissue sample from the axillary process was taken for future genetic stock identification analyses.

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Radiotagged sockeye salmon were tracked using a network of ground-based tracking stations being used for a concurrent Chinook salmon radiotelemetry studies (Figure A1.1; Stuby 2005). Three additional tracking stations were used in 2005 to address sockeye salmon-specific information needs: 1) mainstem Kuskokwim River upstream of Stony River, 2) lower Stony River drainage, and 3) downstream of Telaquana Lake. The ground-based stations consisted of several integrated components similar to Eiler (1995). Tracking stations recorded the date and times the fish were present, signal strength, activity (active or inactive), and location of the fish relative to the station (upriver or downriver). The data was periodically downloaded to a laptop computer, or transmitted to a NOAA geostationary operational environmental satellite (GOES) and downloaded via the internet.

Tracking and Tag Recovery

Aerial tracking surveys were conducted in July, August, and September along the mainstem Kuskokwim River and in major tributaries to identify and locate the fate of radiotagged fish. Survey periods bracketed the period when most sockeye salmon were likely to be on the spawning grounds. Tracking surveys were conducted in one plane with one observer (plus the pilot).

Boat tracking surveys were conducted periodically near the tagging sites to monitor for tags that had been regurgitated. Results from radiotelemetry studies on the Copper River suggested that most fish that expelled tags did so immediately after release (Evenson and Wuttig 2000). Extensive boat tracking was also conducted in Telaquana Lake from July to October to document movement of tagged sockeye salmon in the lake.

Radio tags were recovered opportunistically from fish captured in subsistence fisheries. To encourage voluntary tag recoveries, ADF&G conducted a postseason lottery. Each tag was printed with a toll-free number and mailing address for reporting tag recoveries and for entry into the lottery.

Results and Discussion

Of one hundred sockeye salmon radiotagged in 2005, seventy fish were radiotagged from 24 June to 1 July, nineteen were tagged from 12 to 14 July, and the remaining eleven were tagged on 21 and 22 July (Table A1.1). Deployment included fifty three fish captured on the north bank, thirty nine on the south bank, and eight fish were caught in gillnets. One tagged fish was recaptured at the tagging site, and the radio tag was removed and redeployed in another fish. All model F1835 and F1845 radio tags were deployed during the first tagging period.

Hold Time

Holding time appeared to have an effect on upstream migration. Of ninety two sockeye salmon captured and radiotagged from fish wheels, eight were tagged immediately upon capture, eighteen were held in live boxes <1 hour, twenty six were held >1–2 hours, fifteen were held >2–4 hours, eighteen were held >4–6 hours, and seven may have been held >6 hours. The exact holding time of each fish was unknown, still there appeared to be a holding time effect on upstream migration among our six bins (Figure A1.2).

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Future investigators need to consider this tagging effect in their study design and strive to minimize holding time. Other tagging studies have shown a similar effect on migration speed in sockeye salmon captured with fish wheels (J. Eiler, NOAA/NMFS, personal communication), and recommend short hold times to decrease delays in upstream migration.

Tag Size

Forty model F1845 tags (19 x 51 mm) were deployed, and use of this model was limited to the first tagging period of 24 June to 1 July. Tagged fish ranged between 510 and 610 mm MEF length (average 559 mm). Initially, smaller fish (<550 mm) were included, but the preferred size was increased after crew reported tight insertions that may result in a high risk of stomach rupture in fish <550 mm. Thirty-eight fish (95%) successfully continued their upstream migration. Two fish (5%) in the 550–610 mm length range were detected downstream of the tagging site and did not resume upstream migration. Taggers reported tight insertions of F1845 tags in fish smaller than about 560 mm.

Fifty model F1840 tags (17 x 51 mm) tags were deployed across all three tagging periods. Tagged fish ranged between 415 and 660 mm MEF length (average 554 mm). Forty-one fish (82%) successfully continued their upstream migration. Nine fish (18%) ranging in length between 450 and 570 mm (average length 523 mm) did not resume upstream migration. Crew reported tight insertions of F1840 tags in some fish smaller than about 450 mm MEF length.

Ten model F1835 (17 x 42 mm) tags were deployed, and use of this model was limited to the first tagging period of 24 June to 1 July. Larger fish were targeted with fish ranging between 570 and 625 mm MEF length (average 605 mm). Nine fish (90%) successfully continued their upstream migration, and one fish (10%) measuring 595 mm did not. Crew did not report any difficulties such as tight insertions with the F1835 radio tags.

Of the 3 tags tested, model F1840 gave the best combination of expected tag life and small tag size, and was suitable for the range of fish sizes encountered. The F1845 tag has the largest battery and longest tag life, but use risks stomach rupture in fish <550 mm MEF length. Sockeye salmon <550 mm accounted for 49.2% and 32.7% of sockeye salmon captured in these fish wheels during 2002 and 2003, so model F1845 is not well suited for any future tagging efforts. Although tight insertions that could result in stomach rupture were reported for the F1840 tags in fish <450 mm, crew reported that with care, they could successfully insert this model of tag in sockeye salmon as small as 400 mm MEF. Based on length data from 2002 and 2003, fish <400 mm constituted only 3.9% and 6.4%, of the catch at the Kalskag and Aniak fish wheels. Though the F1835 tag gives the best option for tagging fish <400 mm, it has the smallest battery and thus the shortest tag life of the tags considered, so is less desirable because of concern that tags deployed early in the season may not remain active through the final tracking in September or October.

Distribution

Of the eighty four radiotagged sockeye salmon that successfully resumed upstream migration and entered tributary streams, eleven returned to the Aniak River, one returned to the Holokuk River, fifty one returned to the Holitna River, twenty returned to the Stony River, and one returned to the Swift River (Figure A1.3). Four tagged fish were last detected in the mainstem

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Kuskokwim River; it is unknown if these fish spawned or died in these areas or if the tags were expelled. Five fish passed downstream of the tracking station located downstream of the tagging site, and they did not resume upstream migration. The remaining 7 fish were not detected after tagging and had unknown fates.

Many of the sockeye salmon tagged in this feasibility study traveled to, and presumably spawned in, tributaries not associated with lake habitat. Only fish that traveled to the Aniak and Stony rivers have access to substantial lake habitat for juvenile rearing typical to other systems (e.g., Bristol Bay; Burgner 1991). This was unexpected in part because since 1984 commercial catch sampling shows that approximately 80% of returning adult sockeye salmon spend one winter in freshwater as juveniles before migrating to sea (Molyneaux and Folletti 2005), and the assumption was that this winter was spent in a lake (e.g., "lake-type" sockeye salmon). Progeny of most of the sockeye salmon tagged in this feasibility study must have reared in river habitats (i.e., "river-type" sockeye salmon), even though river-spawning sockeye salmon are often associated with 0-check or "sea-type" juveniles who migrate to sea soon after emergence (e.g., Gilbert 1913; Eiler et al. 1992). According to commercial catch data, 1% or less of Kuskokwim River sockeye salmon are 0-check (Molyneaux and Folletti 2005).

Age and Sex Composition

Of the 100 fish sampled for age information, 84 sockeye salmon had readable scales. Of these fish, age-1.3 was the most common age category (75.0%), followed by age-1.2 (16.7%), age-2.2 and age-2.3 (3.6% each), and age-1.4 (1.2%). The Aniak River fish were 88.9% age-1.3 and 11.1% age-2.2. The single Holokuk River fish was age-1.2. The Holitna River fish were 86.7% age-1.3, 11.1% age-1.2, and 2.2% age-1.4; no Holitna River fish had spent 2 years in freshwater. The Stony River fish were 56.3% age-1.3, 25.0% age-1.2, and 18.8% age-2.3. The single Swift River fish was age-1.3. The overall age composition in radiotagged sockeye salmon were similar to age compositions seen in commercial catch samples in 2005 (Molyneaux and Folletti 2005).

Only 29% of radiotagged sockeye salmon were females. The reasons for this low proportion are unknown, but may be due to selectivity of the fish wheels, poor sex determination by tagging crew, or to actual lower proportions of female sockeye salmon in the Kuskokwim River population. Future studies should take great care in determining the sex of tagged fish and should compare sex ratios with tributary populations.

Relative Run Timing

During this feasibility study, no attempts were made to spread tag deployment throughout the entire run. However, some insight into stock-specific run timing is possible even though sample sizes are small in later tagging periods. Aniak River sockeye salmon were more common later in the season, comprising 4.8%, 28.6%, and 57.1% of the first, second, and third tagging periods, respectively. The Holokuk River fish was tagged during the third tagging period. Holitna River sockeye salmon were more prevalent earlier in the season, and comprised 65.1%, 57.1%, and 28.6% of the first, second, and third tagging periods, respectively. Stony River sockeye salmon were also more common earlier in the run, and comprised 30.2%, 7.1%, and 0% of the first, second, and third tagging periods, respectively. The Swift River sockeye salmon was tagged during the second tagging period. This preliminary information suggests that Kuskokwim River sockeye salmon with longer migration distances may have earlier run timings.

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Conclusions and Recommendations

A full-scale sockeye salmon radiotelemetry project can be successfully executed in the Kuskokwim River drainage. In 2005, 88% of tagged fish successfully resumed upstream migration and 84% were successfully tracked to tributary spawning areas. These success rates are expected to improve after using the results from this feasibility study.

The hold time for sockeye salmon tagged from fish wheels in the Kuskokwim River should be less than one hour. In a full-scale study, this should be monitored closely in order to avoid detrimental tagging effects.

The model F1840 tag gives the best combination of expected battery life and small tag size for the range of sockeye salmon lengths found in the Kuskokwim River. However, fish <400 mm MEF length should not be tagged because of increased risk of stomach rupture. This is expected to exclude <7% of the sockeye salmon captured at the Kalskag fish wheels.

A high proportion of Kuskokwim River sockeye salmon may be "river-type," (i.e., juveniles rear in river habitats). This should be further evaluated in a full-scale study, since managers cannot necessarily apply knowledge gained from lake-type sockeye salmon populations from outside the Kuskokwim River as they may over- or under-estimate the productivity of the system.

This feasibility study suggests that the Holitna River drainage may be an important contributor to the Kuskokwim River sockeye salmon population. In light of possible natural resource development in Holitna and Hoholitna drainages, this should be further evaluated with the full-scale project.

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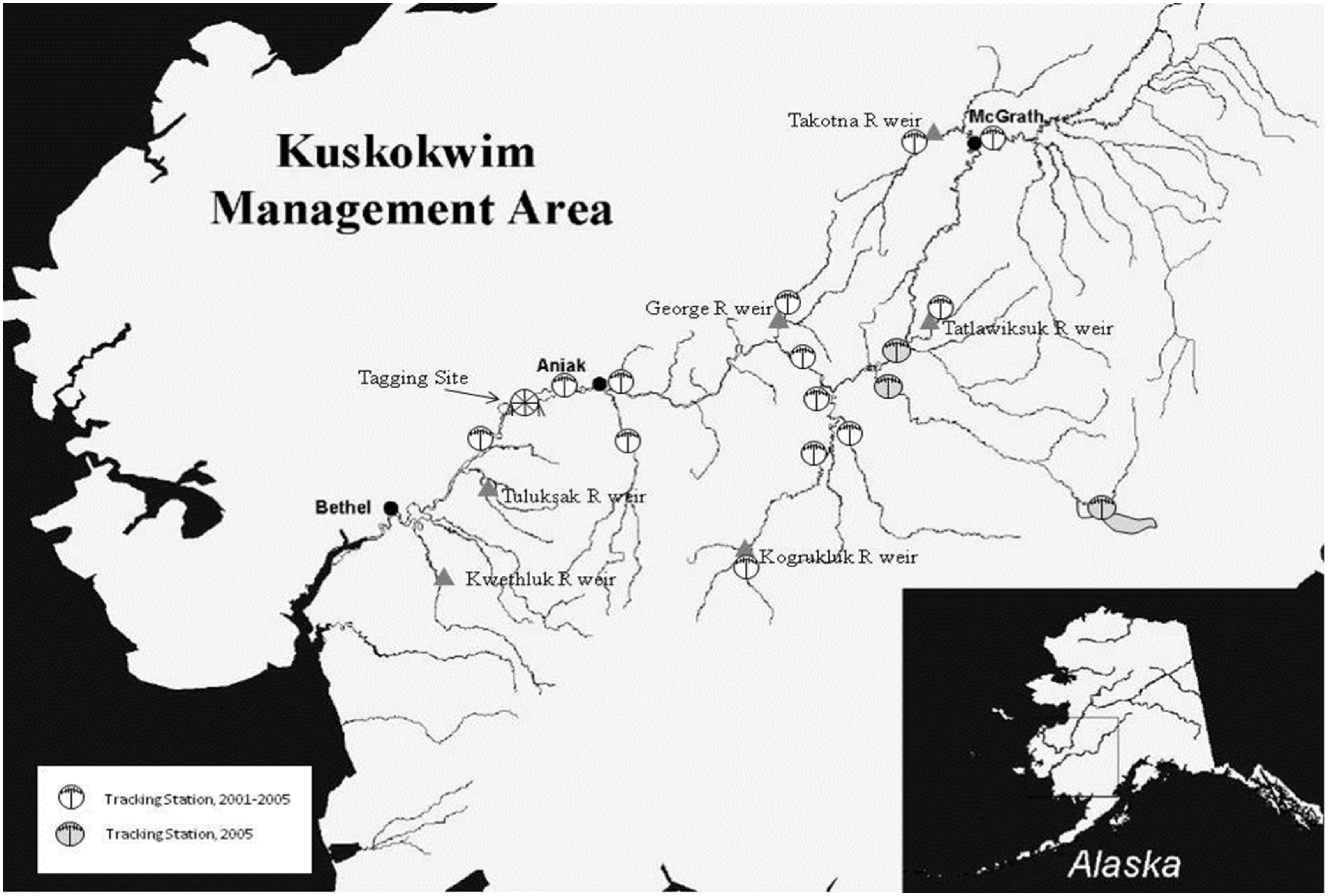
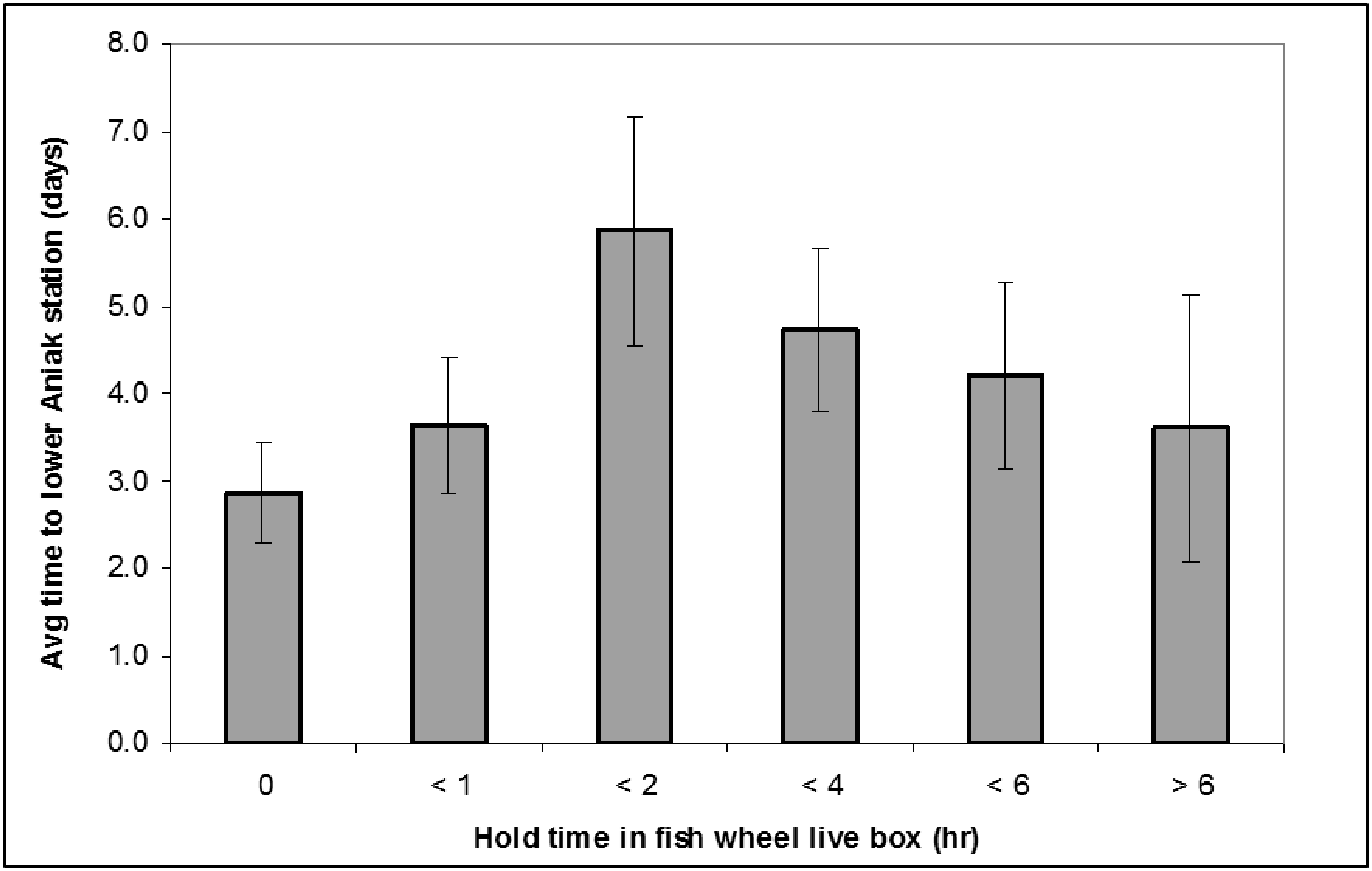
Appendix Table 1.A.1.–Summary of sockeye salmon tag deployment in 2005 by tagging periods, bank of capture, capture method (fish wheels or drift gillnet), and tag model.

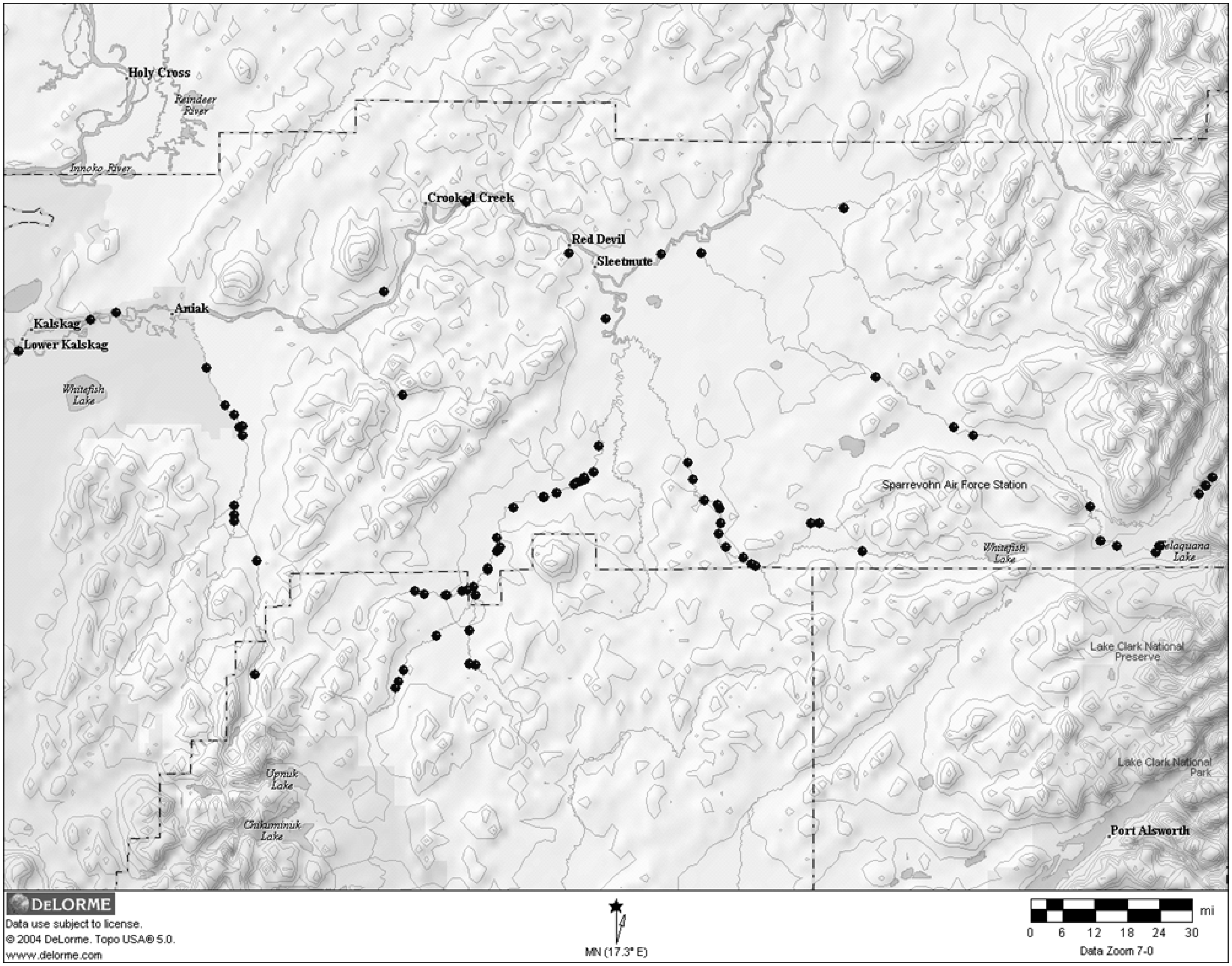
	North Bank			South Bank			Drift Gillnet		
	F1835	F1840	F1845	F1835	F1840	F1845	F1835	F1840	F1845
Period 1 (24 Jun – 1 Jul)	7	9	21	1	9	15	2	2	4
Period 2 (12 – 14 Jul)		9			10				
Period 3 (21 – 22 Jul)		7			4				
Total	7	25	21	1	23	15	2	2	4



Appendix Figure 1.A.1.–Kuskokwim River drainage with locations of escapement monitoring projects, tagging site, and ground-based tracking stations used in 2005.



Appendix Figure 1.A.2.–Average travel time to the first upstream tracking station (36 rkm from the tagging site) for sockeye salmon radiotagged in 2005 and held in fish wheel live boxes for various spans of holding times. Error bars indicate 90% confidence intervals.



Appendix Figure 1.A.3.–Farthest upstream location of Kuskokwim River sockeye salmon radiotagged in 2005.

APPENDIX 1.B: EXPLORATION OF ABILITY TO PROVIDE TOTAL ABUNDANCE ESTIMATES FOR KUSKOKWIM RIVER SOCKEYE SALMON USING MARK–RECAPTURE

Appendix 1.B.1.–Exploration of ability to provide total abundance estimates for Kuskokwim River sockeye salmon using mark–recapture.

Introduction

We explore the potential of using the approach of tag deployment and recovery described herein as a means to estimate total inriver abundance of Kuskokwim River sockeye salmon through a two-event mark–recapture experiment. The requirements for an unbiased estimate are that marked fish do not shed their tags and marked fish behave the same as unmarked fish. In addition at least one of the three following assumptions must be met: every fish has an equal probability of being marked during the first sampling event; every fish has an equal probability of being recaptured during the second sampling event; or marked fish mix completely with unmarked fish between sampling events. To test whether this project design was in violation of these conditions, we examined the marked-unmarked ratios at three recapture sites during the 2006 tagging study.

Methods

In 2006, dedicated tag recovery efforts to examine marked-unmarked ratios were conducted in three sub-basins: the Holitna, Aniak, and Stony rivers. These three locations were selected for more focused radio tag and anchor tag recovery effort based on findings from the 2005 feasibility study. Tag recoveries for the Holitna sub-basin occurred at Kogrukluk River weir, which includes a fish trap annually used to collect salmon age-sex-length data (Liller et al. 2008). Recoveries in the Aniak and Stony sub-basins were attempted through systematic beach seining over a period of six weeks, with a target of 24 seine hauls per week. Recovery crews recorded the total number of fish by species, and the number of radiotagged and anchortagged fish in each seine haul or each day’s weir passage. A chi-square test was used to test the hypothesis that probability of recapture is constant among recovery sites (Sokal and Rohlf 1995).

Abundance estimates were made using radio tags only. The mark–recapture estimate used tags deployed at Kalskag and recaptured at the Kogrukluk River escapement monitoring project (i.e., fish wheel and weir). Abundance estimates were generated using the Chapman estimator and parametric bootstrap estimates of confidence intervals (Efron and Tibshirani 1993).

The Chapman abundance estimator (Seber 1982) based on tag recaptures was calculated as:

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

where:

$\hat{N}^*$ = estimated abundance of salmon in the Kuskokwim River at the Kalskag site,

M = the total number of salmon tagged at the Kalskag site,

C = the total number of salmon examined at the Kogrukluk River recapture weir project, and

R = the total number of tagged salmon recaptured at the Kogrukluk River escapement project.

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Results and Discussion

Sockeye salmon abundance in the Kuskokwim River upstream of Kalskag in 2006 and 2007 was estimated to be 445,860 and 124,336 respectively (Table B1.1). At Kogrukluk River weir, 59,773 fish were observed, including 380 radiotagged or anchortagged sockeye salmon. Beach seining in Telaquana River resulted in a catch of 1,757 sockeye salmon, of which 11 were tagged. Poor water conditions in the Aniak River resulted in only 19 sockeye salmon being captured in the beaching seining, none of which were tagged; consequently, the Aniak River was dropped from further mark–recapture evaluation. No significant difference was found in the marked-unmarked ratios between the Kogrukluk and Telaquana sites (χ^2=0.003, df=1, P=0.96), suggesting the fish had an equal probability of capture at the Kalskag tagging site, and that our study design was not in violation of at least one condition required for an unbiased 2-event mark–recapture experiment.

Although not one of the original objectives of this project, it appears possible to use mark–recapture to estimate total sockeye salmon abundance in the Kuskokwim River. We used our findings to estimate total inriver abundance in 2006 and 2007 to provide some indication of the possible magnitude of total sockeye salmon abundance in the Kuskokwim River (Table B1.1). While we acknowledge limited diagnostic capacity to bolster confidence in these estimates our methodology did appear to perform adequately. Given the level of genetic differentiation that exists among some sockeye salmon populations, it may also be possible to use genetic markers as a means of estimating total abundance, similar to the approach described by Beacham and Wood (1999) and Beacham et al. (2000). Such an approach would require collecting total abundance estimates for a genetically distinct stock as may be possible using a weir at the outlet of Telaquana Lake.

The diagnostics suggest that the tagging methods employed in this study do provide a promising means to estimate total Kuskokwim River sockeye salmon abundance using mark–recapture techniques. Total abundance can be calculated by adding estimated abundance upstream of Kalskag, estimated sockeye salmon escapement in tributaries downstream of Kalskag, and harvest in lower river fisheries. From this, the total abundance of Kuskokwim River sockeye salmon is estimated to be 503,452 in 2006 and 169,569 in 2007 (Table B1.2). We estimate an annual exploitation rate of 9% in 2006 and 20% in 2007. This is much lower than exploitation rates in Bristol Bay, which typically exceed 50% (Salomone et al. 2007), but may have been higher in the past (Figure B1.1). However, in the face of expanding fishery demands, it would be essential for managers to better understand the dynamics of both river- and lake-type sockeye salmon in the Kuskokwim River in order to preserve the biocomplexity that will likely be responsible for their sustainability under changing environmental conditions.

The total inriver abundance and exploitation rates varied between 2006 and 2007, partially due to the near record sockeye salmon run size in 2006. The Holitna River was the major producer of sockeye salmon, followed by the Stony River drainage, and these two systems seem to be dominated by salmon following very different life history patterns. This raises the question of the stability of relative abundance of river-type or lake-type sockeye salmon. In order to harvest sustainably, managers will need to develop stock assessment projects to monitor escapement in a manner that incorporates sockeye salmon population diversity. At a minimum, management

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should strive to monitor both river-type and lake-type life history strategies within the Kuskokwim River. Future work could include tag recovery in both the Holitna River (Kogrukluk River weir) and Stony River (Telaquana Lake) drainages for estimating Kuskokwim River sockeye salmon abundance while still incorporating both life history types.

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Appendix Table 1.B.1.–Abundance estimation for Kuskokwim River sockeye salmon using the Chapman estimator and parametric bootstrap estimates of confidence intervals.

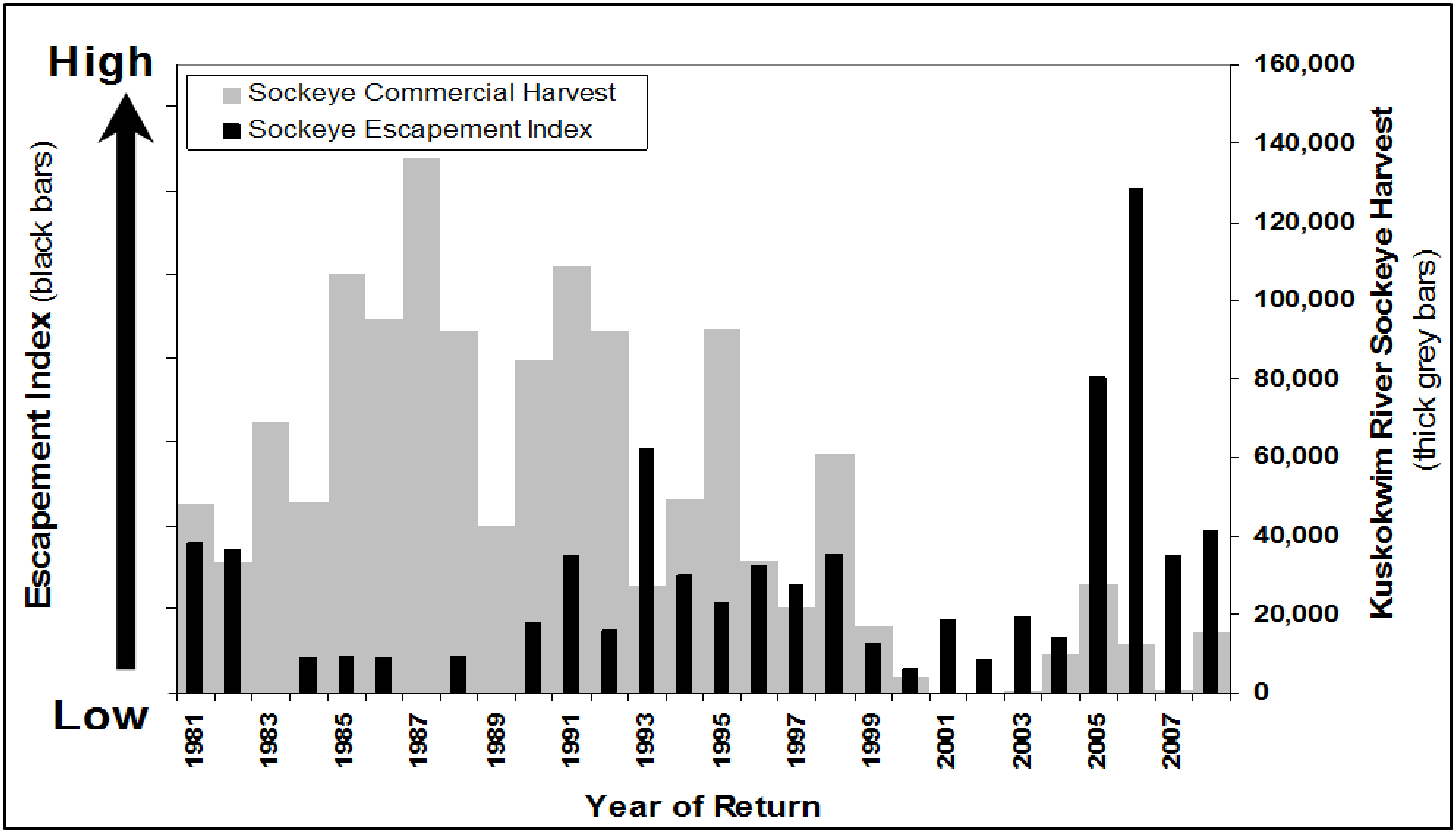
Year	Location	Estimate	Std. Err.	95% CIL	95% CIU
2006	Kuskokwim R. above Kalskag	445,860	58,200	351,762	584,743
	Holitna R.	259,904	40,054	188,082	351,633
2007	Kuskokwim R. above Kalskag	124,336	18,765	93,821	166,341
	Holitna R.	68,245	7,998	48,709	92,549

Appendix Table 1.B.2.–Total run estimates and exploitation rates in 2006 and 2007 for Kuskokwim River sockeye salmon.

Run Component		Method	2006	2007
Harvest				
	Subsistence		30,226	33,234
	Commercial		12,618	703
	Sport		231	382
	Total		43,075	34,319
Escapement				
	Mainstem upstream of Kalskag	Radiotelemetry	445,860	124,336
	Kwethluk	Weir	6,732	5,262
	Kisaralik	Estimate [a]	6,800	5,300
	Tuluksak	Weir	985	352
	Total		460,377	135,250
Total Abundance			503,452	169,569
Annual Exploitation			9%	20%

Note: Annual harvest and weir escapement estimates from 2009 Kuskokwim Area Annual Management Report (Bavilla et al. 2010)

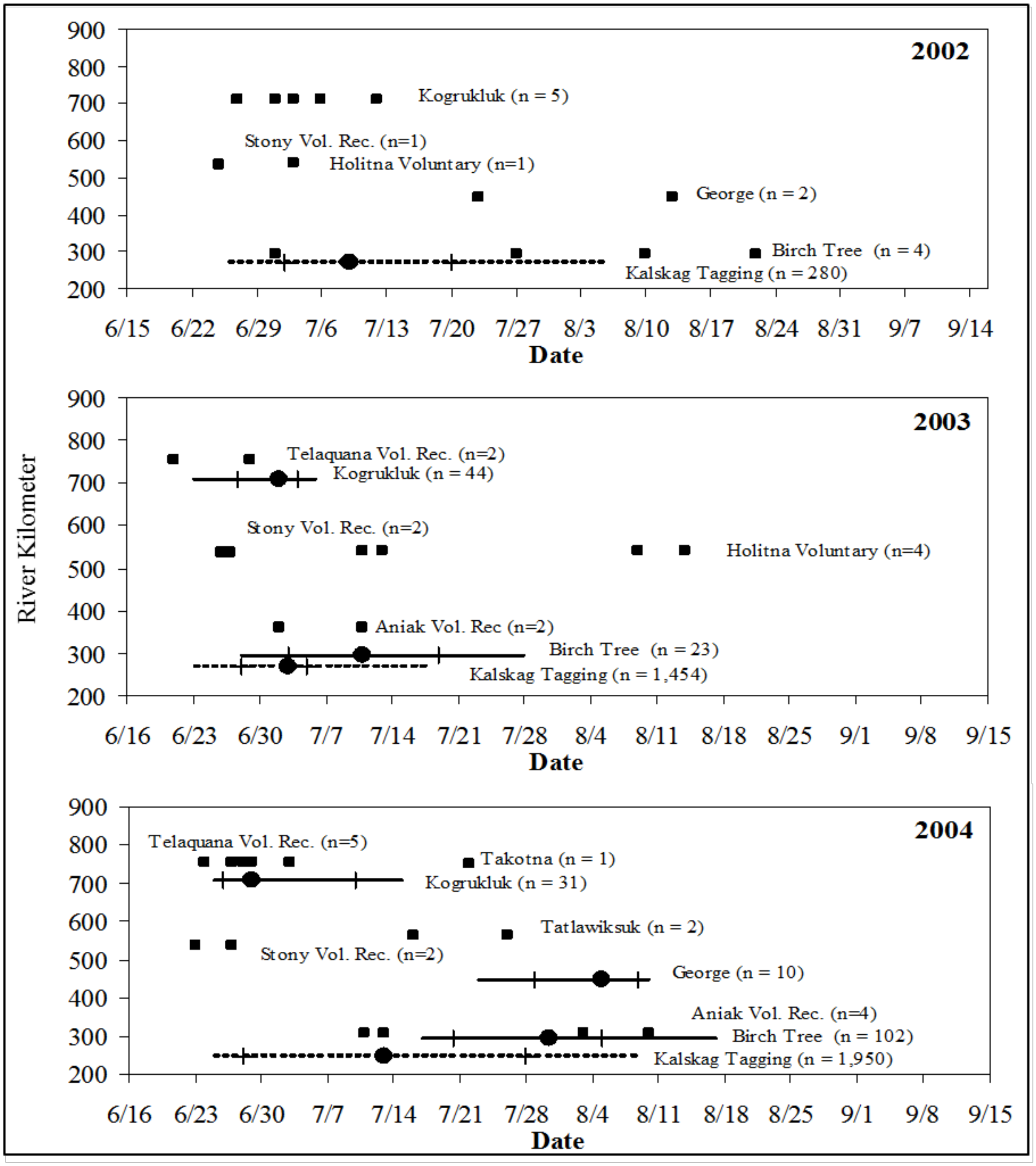
[a] The Kwethluk River weir passage was used as a surrogate for the Kisaralik due to similarity in basin size and morphology.



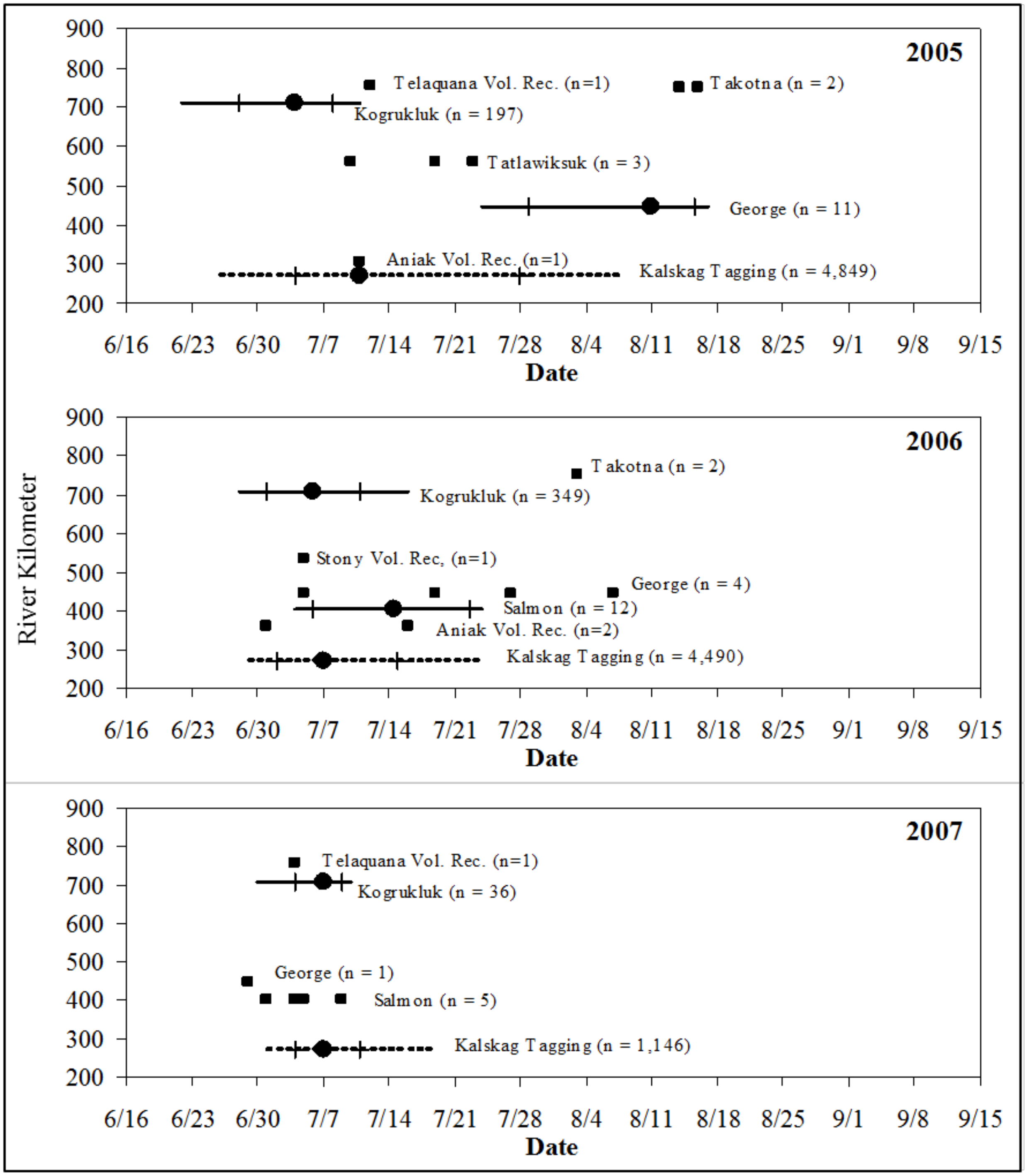
Note: Escapement indices are based on annual Kogrukluk River weir sockeye salmon passage.

Appendix Figure 1.B.1.–Annual escapement index and commercial harvest of Kuskokwim River sockeye salmon.

APPENDIX 1.C: HISTORICAL KUSKOKWIM RIVER SOCKEYE SALMON RUN TIMING



Appendix Figure 1.C.1.–Stock-specific run timing for sockeye salmon anchortagged in 2002–2004, including median (circle), quartile (vertical lines), and 10th and 90th percentile dates (horizontal line). Squares are tagging date for individual fish in tributaries with <5 recovered tags.



Appendix Figure 1.C.2.–Stock-specific run timing for sockeye salmon anchortagged in 2005–2007, including median (circle), quartile (vertical lines), and 10th and 90th percentile dates (horizontal line). Squares are tagging date for individual fish in tributaries with <5 recovered tags.

CHAPTER 2. HABITAT AND GROWTH OF RIVER-TYPE SOCKEYE SALMON IN THE KUSKOKWIM WATERSHED, ALASKA

by

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ABSTRACT

The Kuskokwim River supports a substantial population of sockeye salmon that inhabit riverine habitats for one year post-emergence before migrating to sea. We investigated the types of habitat utilized by these "river-type" juvenile sockeye salmon in a major tributary of the Kuskokwim River and tested the hypothesis that growth of river-type sockeye salmon (back-calculated from adult salmon scales) was comparable to that of "lake-type" sockeye salmon within the Kuskokwim watershed and in other Alaskan lakes. Within riverine habitats, catch per river-seine set (CPUE) was significantly greater in lentic slough habitats compared with flowing side channel and mainstem habitats; although, sockeye salmon inhabiting mainstem habitats were significantly longer than those in side channel and slough habitats. CPUE and length data suggest that juvenile sockeye salmon were actively migrating downstream as they grew older and larger. Telaquana Lake produced the largest juvenile sockeye salmon in the Kuskokwim watershed and lake-rearing sockeye salmon were significantly longer than those inhabiting river habitats. Nevertheless, comparison of juvenile scale growth from adult Kuskokwim salmon (mostly river-type) versus scale growth from lake-rearing sockeye salmon in seven areas of Alaska indicated salmon growth in the Kuskokwim drainage was similar to that of some major sockeye salmon populations and greater than others. Overall, our research indicated that slough habitat, such as that produced by old river oxbows, is especially important to river-type sockeye salmon during early freshwater life (spring) in the Kuskokwim watershed, whereas habitats downstream of the spawning areas are important during later freshwater life. Although lake-type sockeye salmon grew faster than river-type sockeye salmon in the Kuskokwim watershed (primarily in response to growth in Telaquana Lake), growth of river-type sockeye salmon is comparable to or greater than growth of lake-type sockeye salmon in other watersheds.

Key words: Kuskokwim River, Holitna River, Kogrukluk River, Telaquana Lake, river-type sockeye salmon, chum salmon, coho salmon, Chinook salmon, scale growth, habitat.

INTRODUCTION

Three types of juvenile sockeye salmon life history strategies have been described in the literature. The most common is the "lake-type" strategy in which juveniles typically spend one to two years in a lake before emigrating to the ocean. Recent radiotelemetry research (Chapter 1 this document) indicated that most Kuskokwim sockeye salmon follow a "river-type" strategy where they spawn in areas without access to lakes, thus are using riverine habitats, typically rearing and overwintering in river channel and slough areas where water velocity is slow (Wood et al. 1987). Some watersheds also produce a third type of sockeye salmon, known as the "sea-type," which inhabit river habitats for approximately three months or less when no lake rearing habitat is available, [e.g., Harrison River (Fraser watershed), Stikine River, Puget Sound rivers, and Nushagak River] (Schaefer 1951; Wood et al. 1987; Gustafson and Winans 1999; Westing et al. 2005).

"River-type" sockeye salmon are not abundant across the Pacific Rim. Small populations have been observed in the Kamchatka River, Bolshaya River, Mulchatna River (Nushagak drainage), Stikine River, and Taku River (Wood et al. 1987; Burgner 1991; Eiler et al. 1992). This variation in sockeye salmon juvenile life history strategies reflects successful adaptations by sockeye salmon to a variety of freshwater habitat types. However, across the Pacific Rim the relatively low abundance of river-type and sea-type sockeye salmon compared with lake-type salmon (Burgner 1991) suggest productivity of river and sea-type sockeye salmon is lower.

Sampling of the Kuskokwim commercial catch since 1984 indicated that approximately 80% of returning adult sockeye salmon spent one winter in freshwater as juveniles before migrating to sea, and 1% or less of the sockeye salmon migrated to sea during their first year (Molyneaux and Folletti 2005). Chapter 1 of this document demonstrated that most adult sockeye salmon in the Kuskokwim River basin spawn in areas that are not associated with lake habitats. Thus, most juvenile sockeye salmon in the Kuskokwim watershed appear to inhabit riverine habitats for approximately one year after emergence.

The goals of our investigation were to examine habitats used by juvenile river-type sockeye salmon in a major tributary system of the Kuskokwim River (Holitna and Kogrukluk rivers) and to estimate and compare freshwater growth of river-type and lake-type sockeye salmon in major tributaries throughout the Kuskokwim watershed. Habitat types utilized by juvenile sockeye salmon (and other fishes) were examined in the lower Holitna River and one of its major upriver tributaries, the Kogrukluk River (Figure 2.1), during June through September 2006. The Holitna River is known to support river-type sockeye salmon (Baxter[3] 1979) and up to 60,000+ adult sockeye salmon per year have been counted at the Kogrukluk weir (Liller et al. 2008). Salmon growth, which is important to salmon survival (Beamish and Mahnken 2001; Ruggerone et al. 2007), was back-calculated from scales of adult salmon that were radiotracked to tributaries throughout the watershed (Chapter 1 this document) or sampled at weirs and other projects during 2005–2007.

OBJECTIVES

The following specific hypotheses about sockeye salmon habitat and growth were tested:

HABITAT USE BY SOCKEYE SALMON:

1. Juvenile sockeye salmon and other juvenile salmonids randomly utilize river habitat types in the upper and lower Holitna River.
2. Distribution of juvenile sockeye salmon and other salmonids along the upper and lower river and within habitat types remains constant from late June through early September.
3. Mean size of sockeye salmon at a given time period does not differ by main channel versus off channel habitat types or from upper to lower river reaches.

SOCKEYE SALMON GROWTH BY TRIBUTARY:

4. Smolt length and spring growth of sockeye salmon does not differ among smolts originating from each major spawning area and river in the watershed, including clear water, glacial, or turbid rivers, or upper versus lower watershed rivers.
5. Sockeye salmon smolt size does not differ among smolts originating from river-rearing versus lake-rearing habitats, including salmon from other Alaskan watersheds.

METHODS

JUVENILE SALMON ABUNDANCE AND HABITAT

Juvenile salmon were sampled by river seine in the Kogrukluk River, which is a major tributary of the upper Holitna River 709 river kilometers (rkm) from the ocean, and in the lower Holitna River, approximately 491 rkm from the ocean (Figure 2.1). Sampling in the Kogrukluk River occurred primarily within 20 rkm upstream of the ADF&G weir (rkm 710). Sampling in the lower Holitna River primarily occurred within 60 rkm of its confluence with the Kuskokwim River near the village of Sleetmute. Numerous sockeye salmon are known to spawn in the Kogrukluk River (Liller et al. 2008 and Chapter 1 this document), whereas little, if any, spawning occurs in the lower Holitna River (few gravel areas). Sampling occurred from late June

[3] Baxter, R. Unpublished. Hoholitna River reconnaissance survey, 1977. Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region Kuskokwim Salmon Resource Report No. 3, Anchorage.

through early September, 2006. Sampling frequency was approximately every two weeks in the Kogrukluk River and once per month in the lower Holitna River.

The river seine was designed to sample juvenile salmon in low to moderate velocity rivers (Ruggerone et al. 2007). The net was 20 m long, 2 m deep at the center, 1 m deep at the wings, and mesh size ranged from 12 mm at the wings to 3 mm at the center. When deploying the river seine, the upstream end was walked downstream at the same speed as the river current while the boat carried the lower end of the net to another biologist approximately 33 m downstream (Appendix 2.A). Surface area sampled by the river seine is approximately 400 m^2.

Upon retrieval of the river seine, all fish were placed in one or more buckets. Fishes were identified and counted. The salmon catch was randomly sampled for length measurements until approximately 30 sockeye salmon of each age class was obtained during each sampling period. A portion of the salmon were preserved in 10% buffered formalin and then sent back to the lab where species identification was checked and corrected when necessary. Scales were removed from sockeye salmon for measurement (see below) and fish length was re-measured.

Juvenile sockeye salmon and other salmonids were sampled in three habitat types: mainstem, flowing side channel, and slack water slough. Slough habitats included both spring fed and river back-water areas. Diversity of habitat types was much greater in the Kogrukluk River compared with the lower Holitna River, a wide (~150 m) low gradient river (Appendix 2.A). Most catch per effort statistics are reported as geometric mean values (as opposed to arithmetic mean) because salmon catch data are positively skewed (many small catches and few large catches). Application of the log-transformation normalized the frequency distribution of catch data, a requirement for statistical analyses. The geometric mean catch is smaller than the arithmetic mean catch, and it is a better representation of central tendency when data are strongly positively skewed. ANOVA of log-transformed catch data was used to test hypotheses related to habitat types occupied by sockeye salmon of various sizes (Zar 1996). Although sockeye salmon is the targeted species of this investigation, we also present abundance and habitat data for other salmonids.

SOCKEYE SALMON LENGTH VERSUS SCALE RADIUS RELATIONSHIP

We attempted to collect at least 10 juvenile sockeye salmon per 10 mm length interval in order to develop a relationship between body length and scale radius (Henderson and Cass 1991; Fukuwaka and Kaeriyama 1997) that could be used to back-calculate length of juveniles from scales collected from adult sockeye salmon in each tributary of the Kuskokwim watershed. Juvenile sockeye salmon collected from the Holitna drainage were supplemented with juvenile sockeye salmon (mostly smolts) collected while migrating downstream from the outlet of Telaquana Lake during June 13–15, 2006. Scales were removed from the preferred area (Koo 1962), placed on a numbered gum card, and pressed into heated acetate cards at the laboratory. Scale measurements followed procedures described by Davis et al. (1990) and Hagen et al. (2001). After selecting a scale for measurement, the scale was scanned from a microfiche reader and stored as a high resolution digital file. High resolution (3352 x 4425 pixels) allowed the entire scale to be viewed and provided enough pixels between narrow circuli to ensure accurate measurements of circuli spacing (Figure 2.2). The digital image was loaded in $Optimas_1$ 6.5 image processing software to collect measurement data using a customized program. The scale image was displayed on a high resolution monitor and the scale measurement axis was consistent with that for adult scales (approximately 22° from the longest axis). Distance (mm) between circuli was measured within each growth zone [i.e., from the scale focus to the outer edge of the first freshwater annulus (FW1) and to the outer edge of the spring plus growth zone (FWPL), which represents growth during smolt migration in freshwater and/or estuarine habitats].

A variety of approaches have been used to back-calculate fish lengths from scale radii measurements (Francis 1990). We explored the Fraser-Lee procedure recommended by Ricker (1992). However, the Fraser-Lee procedure was not appropriate to back-calculate juvenile salmon length from adult scales because some adult scales were resorbed along the outer edge, and allometry of scales and salmon length changes from juvenile to adult life stages (Fisher and Pearcy 2005). Therefore, as recommended by Fisher and Pearcy (2005), we utilized geometric mean regression of juvenile salmon length (mm) on total scale radius (mm) to back-calculate juvenile length from adult scales collected in the watershed. Pierce et al. (1996) concluded that various back-calculation methods produced equivalent results, especially when variability in the fish length versus scale radius relationship was low. The slope of the geometric mean regression was calculated from the ratio of length standard deviation to scale radius standard deviation. The Y-intercept of the regression could then be calculated using algebra because the regression crosses mean Y and mean X values. All lengths are reported as live lengths. Preserved fish lengths were multiplied by 1.042 to account for shrinkage when preserved in 10% buffered formaldehyde (Rogers 1964). Reported values are mean ±1 standard error (SE) unless noted otherwise.

JUVENILE SOCKEYE SALMON LENGTH BY WATERSHED

Scales were collected from the preferred scale area of age-1.3 adult sockeye salmon (one winter in freshwater, three winters in ocean) returning to known tributaries in the Kuskokwim watershed during 2005 (pilot study), 2006, and 2007. Numerous salmon scales were collected each year from sockeye salmon captured with fish wheels operated near Kalskag (rkm 270; Figure 2.1), then live-released after tagging with an esophageal radio transmitter (Chapter 1 this document). Spawning area of tagged salmon was determined by aerial surveys and by ground-based receiver stations located in select drainages (note: some tagged fish did not successfully escape into spawning tributaries, and these fish were pooled into a “Kuskokwim River” group which represented a mix of sockeye salmon of unknown origin). Scales from tagged salmon were supplemented with age-1.3 sockeye salmon scales collected from weirs on the Kwethluk, George, Tuluksak, Kogrukluk and Salmon rivers, and a sonar project operated on the Aniak River (Figure 2.1). Additional adult scales were collected from fish captured by beach seine in Telaquana Lake and in the upper Telaquana River (0.5 km from lake) as adults approached the lake. Some scales collected from weir and sonar projects exhibited resorption along the outer margin of the scale, therefore ocean age was determined from length frequency distributions of ocean age-2 (two winter annuli) and ocean age-3 (three winter annuli) male and female salmon whose scales had not resorbed.

Adult scales were selected for measurement only when salmon age was in agreement between two scale readers. Scales having an abnormal focus were excluded (e.g., unusually great growth to first circuli). Methods for measuring adult salmon scales were the same as for juvenile salmon. The scale measurement axis was determined by a perpendicular line drawn from a line intersecting each end of the first salt water annulus approximately 22° from the longest axis (Figure 2.2). Growth zones corresponding to seasonal and annual scale growth were measured. Growth zone FW1 is the area between the scale focus and the outer edge of the first freshwater annulus, growth zone FWPL represented growth between FW1 and the beginning of ocean growth, growth zones SW1, SW2, and SW3 represented annual ocean growth, and growth zone SWPL represented growth after the last ocean annulus. The distance (mm) between circuli was measured within each growth zone. The habitat in which FWPL growth occurs is unknown, but it likely includes both freshwater and possibly estuarine habitats. Data associated with the scale (i.e., date of collection, location, sex, length, and capture method) were included in the dataset. Only data associated with FW1 and FWPL growth are reported here.

Juvenile sockeye salmon length at the end of the first year in freshwater (FW1) and at the end of the smolt transition period (FW1 and FWPL) was estimated from the aforementioned fish length-scale radius relationship and adult salmon scales. Preliminary analyses indicated the ranking of back-calculated lengths among the watersheds was not consistent each year (significant interaction effect); therefore, estimated lengths in each watershed were compared using ANOVA for each year of data. Adult salmon scales reflect growth of fish that survived rather than the total population inhabiting the watershed as juveniles. Smaller salmon tend to experience higher mortality; therefore, back-calculations of size from adult scales likely over-estimated average salmon size and underestimated variability in size.

COMPARISON OF KUSKOKWIM SOCKEYE SALMON GROWTH WITH OTHER STOCKS

Adult sockeye salmon were randomly sampled from the Kalskag fish wheel catch (Chapter 1 this document); therefore, juvenile lengths estimated from these adult scales represent a random sample of sockeye salmon primarily rearing in the middle upper watershed and upstream. Freshwater scale growth of adults sampled at Kalskag was compared with scale growth from age-1.3 sockeye salmon sampled from seven other watersheds in Alaska (Kvichak, Egegik, Nushagak District, Black Lake, Kasilof, Kenai, Coghill) during the past 30 to 40 years (Ruggerone and Rogers 1998). These watersheds represent four regions of Alaska where most lake-type sockeye salmon are found (e.g., Bristol Bay, Chignik, Cook Inlet, and Prince William Sound). Methods used to measure scale annuli and freshwater spring growth of sockeye salmon from these other watersheds was the same as that used for Kuskokwim sockeye salmon.

RESULTS

HABITAT UTILIZATION IN THE KOGRUKLUK RIVER

Subyearling sockeye salmon were the most abundant fish sampled in the Kogrukluk River during late June through late September, 2006, averaging approximately 158 fish per seine set. Geometric mean (g.m.) catch per seine set (CPUE) of juvenile sockeye salmon was consistently high from late June through early August (g.m.=47 sockeye salmon), then declined sharply to approximately 3 salmon per set during late August through late September (Figure 2.3). No yearling sockeye salmon were captured indicating most yearlings had moved downstream prior to late June.

CPUE of subyearling sockeye salmon was significantly greater in slough habitats (g.m.=35.5 fish; $P<0.001$) and side channel habitats (g.m.=16.1 fish; $P=0.014$) compared with mainstem habitats (g.m.=4 fish; two factor ANOVA: df=2, 62; $F=11.415$, $P<0.001$) (Figure 2.4; Table 2.1). Catch of sockeye salmon was 100% greater in slough versus side channel habitats, but the difference was not statistically significant ($P=0.126$), owing to the high variability in catch.

Chum salmon fry were highly abundant in late June (g.m.=74 chum salmon), but catch declined precipitously to two chum salmon per set in early July and to 0.4 chum salmon per set for the remainder of the season (Figure 2.3). CPUE of subyearling chum salmon did not vary significantly by habitat type (P>0.05), although CPUE tended to be greatest in side channel habitats during late June and mainstem habitats during early July (i.e. the period when chum salmon were most abundant) (Figure 2.4; Table 2.1).

Identification of Chinook versus coho salmon could not be confirmed during late July and August (no samples preserved), although fish identifications from other dates were confirmed. Subyearling Chinook salmon were relatively abundant in the Kogrukluk River and CPUE declined from 19.0 Chinook salmon per set in late June to 13.7 per set in late July (unconfirmed identification) and to approximately 1.5 Chinook salmon per set during early August through late September (Figure 2.3). Yearling Chinook salmon were rarely captured. In contrast with sockeye salmon, subyearling Chinook salmon were significantly more abundant in mainstem habitats (g.m.=27.5 fish; P<0.001) compared to slough habitats (g.m.=5.9 fish; P<0.001) during late June and early July (Figure 2.4; Table 2.1). Chinook salmon catches in side channel habitats were intermediate (g.m.=11 fish).

Subyearling coho salmon were rarely captured during late June and early July. CPUE of subyearling coho salmon increased to 16.5 fish per set in early August (unconfirmed identification) followed by less than one coho salmon per set during late August and September. Most subyearling coho salmon were captured in mainstem habitats (Figure 2.4; Table 2.1). Yearling coho salmon were rarely captured during late June through September (0.3 fish per set).

Juvenile whitefish *Coregonidae* spp. averaged less than one fish per set during late June through September and there was no difference in CPUE between habitats. CPUE of other fishes (sculpins *Cottidae* spp., juvenile grayling *Thymallus arcticus*, and northern pike *Esox lucius*) peaked in late July (Figure 2.3), and there was no difference in CPUE between habitats (Table 2.1). No rainbow trout *Oncorhynchus mykiss* and only 4 char *Salvelinus* spp. were captured in the Kogrukluk River.

HABITAT UTILIZATION IN THE LOWER HOLITNA RIVER

Subyearling sockeye salmon were the third most abundant species group sampled by beach seine in the lower Holitna River from late June through mid-September, 2006. CPUE increased from 0.7 fish per set in late June to 5.7 fish per set in late July, and then declined to 0.4 fish per set in August and September (Figure 2.5). CPUE of sockeye salmon in the lower Holitna River was much less than CPUE in the Kogrukluk River.

Side channel and slough habitats were less common in the lower Holitna River compared to the Kogrukluk River. During late July, when nearly all sockeye salmon fry were captured, sockeye salmon fry were significantly more abundant in mainstem habitats compared with side channel habitats (df=1, 20; F=5.399, P=0.031). Slough habitats were not sampled during this period.

CPUE of chum salmon peaked in late June (33.5 fish per set), were rarely captured in late July (0.2 fish per set), and were not captured in August and September (Figure 2.5). CPUE of chum salmon did not differ between mainstem and side channel habitats.

Chinook salmon fry and yearlings were rarely captured in the lower Holitna River, averaging less than 0.1 fish per set (Figure 2.5). No coho salmon were captured. Other fishes, numerous young-of-the-year and some older whitefish, sucker *Catostomidae* spp., grayling, northern pike, and sculpin, were exceptionally abundant in the lower Holitna River, especially during late July and mid-September (Figure 2.5). No char or rainbow trout were captured. Numerous large sheefish *Stenodous Leucichthys* were observed in mid-channel, but none were captured in the seine.

JUVENILE SALMON SIZE IN THE KOGRUKLUK AND HOLITNA RIVERS

Length of subyearling sockeye salmon captured in the Kogrukluk River increased from approximately 32 mm in late June to 50 mm in early August, and remained relatively constant from early August to late September (Figure 2.6) when few sockeye salmon were captured (Figure 2.3). The increase in length per day (approximate growth rate) from late June through late July was 0.56 mm (Figure 2.7). Sockeye salmon length in the lower Holitna River was approximately 8 mm greater in late June and 13 mm greater in late July compared with sockeye salmon in the Kogrukluk River.

Length of sockeye salmon in mainstem, side channel, and slough habitats of the Kogrukluk River was compared during late June and early July when measurements were available in each habitat. Sockeye salmon length was significantly longer in mainstem versus side channel habitats (Figure 2.8; two factor ANOVA, df=2, 199, F=37.569, $P<0.001$). Sockeye salmon length was smaller in slough habitats versus mainstem and side channel habitats. Sufficient length data were not available in each habitat during subsequent periods for statistical comparisons, but length tended to be greater in mainstem habitats compared with side channel and slough habitats.

Length of chum salmon steadily increased from 42 mm in late June to 57 mm in late July, or an average daily increase of 0.6 mm (Figures 2.6 and 2.7). Chum salmon size was nearly identical in the Kogrukluk and Holitna rivers.

Length of subyearling Chinook salmon in the Kogrukluk River increased from approximately 41 mm in late June to 64 mm in late July then remained relatively stable for the remaining season when few Chinook salmon were captured (Figure 2.6). The increase in length per day from late June through late July was 0.8 mm (Figure 2.7). Coho salmon were slightly smaller, on average, compared to Chinook salmon and the increase in length per day was 0.9 mm. Too few Chinook and coho salmon were captured in the Holitna River to calculate mean size.

SOCKEYE SALMON LENGTH-SCALE RADIUS RELATIONSHIP

Juvenile sockeye salmon length was correlated with total scale radius (r=0.91). The following geometric mean regression was used to back-calculate juvenile length from adult scale measurements (Figure 2.9):

$$\text{Live length (mm)} = 27.77 + 152.51\ (\text{scale radius (mm)}), \qquad (1)$$

n=293, R^2=0.82, overall $P<0.001$. The 95% confidence interval about a predicted salmon length of 100 mm is ±13 mm.

This relationship was compared to the same relationship developed with juvenile sockeye salmon from the Chignik watershed (Alaska Peninsula; Ruggerone and Rogers 1998). Back-calculation of sockeye salmon length using the Kuskokwim model was 4% greater (2 mm) than that predicted by the Chignik model when the predicted length was small (e.g., 52 mm), but it was 2.2% less (2.5 mm) when the predicted length was large (e.g., 112 mm). When comparing length back calculations from the 1,088 freshwater scale measurements of adult Kuskokwim sockeye salmon using the 2 models, sockeye salmon length was 1.5% less (1.4 mm), on average, at the end of the first growing season (FW1) and 2.2% less (2.4 mm) at the end of spring plus growth (FWPL) when applying the Kuskokwim versus Chignik scale model. These findings provide initial evidence that salmon length to scale radius relationships is somewhat robust between stocks and between years.

Sockeye Salmon Length by Watershed

Sockeye salmon scales were examined from adult salmon returning to 16 drainages within the Kuskokwim watershed. These drainages ranged from the Kwethluk River in the lower watershed (rkm 131) to Telaquana Lake in the upper watershed (rkm 756). Juvenile sockeye salmon lengths were back-calculated from 1,088 adult sockeye salmon scales collected during 2005 (56 scales), 2006 (568 scales), and 2007 (464 scales). These fish reared in freshwater during 2001, 2002, and 2003, then emigrated to sea during 2002, 2003, and 2004, respectively. Text that follows refers to the juvenile salmon by the year in which they returned as adults (i.e., four years after the first growth season and three years after the spring growth (smolt) season).

Mean back-calculated length of sockeye salmon at the end of the first growing season (FW1) ranged from 81 ± 2.3 mm in Two Lakes (Stony River watershed) to 108 ± 1.4 mm in Telaquana Lake (also Stony River dainage) when samples from all years were combined (Figure 2.10). Mean length of sockeye salmon at the end of the spring smolt period (FW1 and FWPL) ranged from 96 ± 2.3 mm in upper Aniak River to 117 ± 1.3 mm in Telaquana Lake (Figure 2.10). Back-calculated mean growth during spring transition (FWPL) ranged from 2 ± 1.1 mm in the Tuluksak River to 27 ± 3.0 mm among juveniles produced by adults from the unspecified Kuskokwim River group (note: the “Kuskokwim River” group represented a mixture of tagged sockeye salmon for which spawning tributary/habitat could not be determined). It is important to note that these mean length estimates are influenced by unequal sample sizes and growth during each year (Table 2.2; see additional analyses that follow).

Growth of juvenile sockeye salmon was compared between Kuskokwim tributaries in 2006 and 2007. During 2006 and 2007 (2002 and 2003 growth years) Telaquana Lake produced the largest juvenile sockeye salmon at the end of the first growing season (FW1), averaging 110 mm and 106 mm, respectively (Figure 2.11, Table 2.2; $P<0.05$). Telaquana Lake sockeye salmon were also significantly longer, on average, than most other stocks at the end of spring growth during the smolt period (when sample size exceeded 10 fish) ($P<0.05$, Table 2.2). Spring growth (FWPL) of Telaquana Lake sockeye salmon during the smolt migration period was less than other stocks in 2007, but typical of other stocks in 2006.

Sockeye Salmon Length by Habitat Type

Back-calculated lengths of river-rearing sockeye salmon were compared with back-calculated lengths of lake-rearing sockeye salmon. Nearly all lake-rearing sockeye salmon were from Telaquana Lake. Across the 3 years of study, the average length of sockeye salmon at the end of the first growing season (FW1) was significantly smaller among river-rearing sockeye salmon (89 mm) compared with lake-rearing salmon (103 mm; Figure 2.12; two factor ANOVA (year, location): $df=2, 1083$; $F=45.56$; $P < 0.001$). Likewise, the average length at the end of the spring transition period (FW1 and FWPL) for river-rearing sockeye salmon (105 mm) was significantly smaller than lake-rearing salmon (118 mm; Figure 2.12; two factor ANOVA: $df=2, 1083$; $F=25.24$; $P<0.001$). Growth during the spring smolt period (FWPL) was not significantly different between river- and lake-rearing sockeye salmon ($P>0.05$).

Sockeye Salmon Length by Study Year

Juvenile lengths back-calculated from adult salmon scales collected from the Kalskag fish wheel represent a random sample of sockeye salmon primarily rearing in the middle and upper Kuskokwim River watershed, as noted above. Mean lengths of these juvenile sockeye salmon at the end of the first season were 89 ± 1.6 mm in 2005, 93 ± 0.8 mm in 2006, and 87 ± 0.8 mm in 2007. Mean length of sockeye salmon in 2006 (93 mm) was significantly greater than lengths in 2005 and 2007 (multiple range test, $P < 0.02$). Mean lengths of juvenile sockeye salmon at the end of spring growth (FW1 and FWPL) were significantly different during each year ($P < 0.001$): 107 ± 2.3 mm in 2005, 97 ± 0.9 mm in 2006, and 115 ± 1.2 mm in 2007. Significant differences in length at the end of the spring growth period were strongly influenced by significant differences in spring growth (FWPL). FWPL was low in 2006 (4 ± 0.6 mm), moderate in 2005 (18 ± 2.7 mm), and high in 2007 (27 ± 1.4 mm). These data indicated that sockeye salmon that grew slowly during the first season in freshwater (e.g., 2007) experienced relatively large growth during the following spring; whereas, salmon that grew fast during the first season (e.g., 2006) experienced relatively little growth during the following spring. Greater growth of 2006 salmon may have been related to relatively high air temperature at Bethel from May to September 2002 (avg. 51.6°F) compared with adjacent years (47.6–50.6°F). Spring growth of salmon appeared to be influenced by temperature, which was high during May and June in 2004 (51.5°F) and relatively low during 2003 (48.6°F).

Comparison of Kuskokwim Sockeye Salmon Growth with Other Stocks

Scale growth in Kuskokwim sockeye salmon (based on Kalskag samples) during the first year (FW1) was smaller, on average, than that of Egegik and Kvichak salmon, similar to that of Nushagak, Kenai, and Kasilof salmon, and larger than that of Black Lake and Coghill sockeye salmon (Figure 2.13). Growth of Kuskokwim sockeye salmon at the end of the following spring transition period (FW1 and FWPL) was similar to that of Egegik, Kvichak, Nushagak, and Black Lake sockeye salmon, and greater than that of Kenai, Kasilof, and Coghill Lake sockeye salmon. These data provide evidence that growth of Kuskokwim sockeye salmon in freshwater was similar to that of some major sockeye salmon populations and greater than others. Kuskokwim sockeye salmon tagged at Kalskag were dominated by sockeye salmon that spawned in rivers without access to lake habitat (94% of total), indicating that scale growth of river-type sockeye salmon in the Kuskokwim watershed (FW1: 0.41 mm; FW1 and FWPL: 0.51 mm) was comparable to scale growth of lake-rearing sockeye salmon located on other regions of Alaska (FW1: 0.23–0.55 mm; FW1 and FWPL: 0.25–0.55 mm).

DISCUSSION

Juvenile Sockeye Salmon Habitat

Subyearling sockeye salmon were especially abundant in slough habitats of the Kogrukluk River during spring. Slough habitats include both mainstem backwater areas and lentic areas supported by spring water. Many of the sloughs were old oxbows that were created when the river changed course. Some sloughs also supported spawning habitat and easy access for their progeny. Slough habitat was prevalent in the Kogrukluk and Holitna rivers (Appendix 2.A). Water velocity in these habitats was minimal and provided shallow lentic habitat that was similar to lake habitat where juvenile sockeye salmon are typically found.

Abundance of juvenile sockeye salmon in the Kogrukluk River declined sharply after early August, apparently in response to emigration (rather than mortality). Emigration of sockeye salmon from habitats near the spawning grounds may have been influenced by declining water levels that reduced availability of slough habitat. However, the relatively large size of sockeye salmon in mainstem versus slough habitats and in the lower Holitna River versus the Kogrukluk River suggests the emigration may have been active rather than passive. Larger salmon in mainstem habitats and in the lower river likely reflect somewhat older salmon (in terms of days), but they could have also been faster growing individuals.

Juvenile sockeye salmon abundance in the lower Holitna River peaked in late July. This area supports few if any spawning sockeye salmon, therefore sockeye salmon in this area originated from upstream areas, including the Kogrukluk River. In the lower Holitna River, juvenile sockeye salmon were typically observed in shallow low velocity areas of the mainstem and within side channels. The decline of sockeye salmon abundance in the Kogrukluk and Holitna rivers after late July raises the question: where do juvenile sockeye salmon reside during fall and winter? Some sockeye salmon may have dispersed offshore and into the river beyond the reach of the river seine as water level and velocity declined. Other salmon may have dispersed further downstream in the mainstem Kuskokwim River and associated habitats.

The Kuskokwim River supports one of the largest populations of coho salmon in Alaska, therefore predation by coho salmon on emerging sockeye salmon fry was considered. However, unusually few subyearling and yearling coho salmon and no 2-year old coho salmon smolts were observed while sampling for sockeye salmon from late June through September. A few yearling coho salmon were observed in large pools and beaver ponds adjacent to the Kogrukluk River during late June, but few if any sockeye salmon fry were present in these habitats. These observations suggest predation by coho salmon on sockeye salmon fry, which can be significant in lakes (Ruggerone and Rogers 1992), was not significant in these riverine areas.

Sockeye Salmon Length by Watershed

A geometric mean regression was developed to estimate juvenile Kuskokwim sockeye salmon length from scale radii measurements of adult salmon returning to 16 areas of the Kuskokwim watershed. Back-calculated lengths of juvenile sockeye salmon at the end of the first year in freshwater (range of means: 81–108 mm) were relatively great compared with lengths of sockeye salmon smolts (e.g., 87 mm for age-1 Kvichak smolts (Ruggerone and Link 2006), or 90 mm for Telaquana Lake smolts in 2006). The relatively large back-calculated length of Kuskokwim sockeye salmon likely reflects size-selective mortality of smaller sockeye salmon. Back-calculated length of sockeye salmon at the end of the spring transition period should not be directly compared with length of smolts because FWPL scale growth may include growth that occurred in the estuary in addition to the river during smolt migration. Back-calculated length of sockeye salmon should not be directly compared with lengths of juvenile sockeye salmon captured in the Kogrukluk River and in the lower Holitna River because these samples were not random, as indicated by the lack of length increase after late July (Figure 2.6).

Lengths of lake-type sockeye salmon in the Kuskokwim River were significantly greater than lengths of river-type salmon. This finding reflects the large size of Telaquana Lake sockeye salmon relative to other sockeye salmon in the watershed. Telaquana Lake, which likely supports the largest populations of lake-rearing sockeye salmon in the Kuskokwim watershed, produces relatively large sockeye salmon even though the lake is often glacial. Conceivably, the long back-calculated lengths of Telaquana sockeye salmon could reflect size-selective predation as smolts migrate a tremendous distance to the ocean (756 rkm). However, back-calculated lengths of sockeye salmon from Two Lakes (also in the Stony River watershed) were smaller than most river-type sockeye salmon populations, indicating size-selective predation was not especially high for upriver populations.

Sockeye salmon scales from the Kuskokwim River were similar or larger in size to those of other major sockeye salmon populations in Alaska, suggesting growth of river-type sockeye salmon in the watershed is favorable. Growth of sockeye salmon is typically density-dependent, but the effects of density on growth of river-type sockeye salmon in the Kuskokwim watershed have not been examined. Kuskokwim sockeye salmon appear to maintain favorable growth while shifting their distribution from slough habitats in the upper watershed during spring to downstream habitats during late summer and fall.

ACKNOWLEDGEMENTS

This investigation was funded by the AYK Sustainable Salmon Initiative. We thank ADF&G and Kuskokwim Native Association biologists and technicians who contributed to data collection in the field. We also thank Jeanette and Jerry Mills, who collected samples from Telaquana Lake. Sockeye salmon scales were scanned and measured by W. Rosky and M. Lovejoy.

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TABLES AND FIGURES

Table 2.1.–Geometric mean catch per river seine haul of age-0 salmon, non-salmonids, and whitefish in the Kogrukluk River during 2006.

Habitat	n	Geometric mean	Lower SE	Upper SE
Sockeye Salmon (June to late September)				
Mainstem	22	4.0	1.6	10.4
Side channel	28	16.1	5.9	41.1
Slough	33	32.5	11.0	81.4
Chum Salmon (late June & early July)				
Mainstem	8	28.3	15.1	87.7
Side channel	9	13.5	8.7	49.0
Slough	8	9.1	5.2	28.9
Chinook Salmon (late June & early July)				
Mainstem	10	27.5	11.0	73.0
Side channel	15	11.1	4.3	29.0
Slough	10	5.9	2.9	16.7
Coho Salmon (late July & early August)				
Mainstem	5	48.0	25.9	150.9
Side channel	10	4.3	2.3	12.7
Slough	7	9.2	5.9	32.4
Non-salmonids (June to late September)				
Mainstem	22	5.1	1.5	12.1
Side channel	28	3.5	0.9	8.1
Slough	33	4.6	1.2	10.8
Whitefish (June to late September)				
Mainstem	22	0.4	0.2	1.0
Side channel	28	0.1	0.1	0.4
Slough	33	0.0	0.0	0.1

Note: CPUE during periods when species were relatively abundant. Sample periods excluded if overall catch rates were low.

Table 2.2.–Mean back-calculated length of sockeye salmon at the end of the first growth year (FW1) and after spring growth during the following year (FW1 & SWPL), and growth during spring of the smolt migration (FWPL).

Life stage	Adult year	Growth year	Location	River km [a]	Length (mm)	SE	n	Skewness
FW1	2005	2001	Stony R [b]	536	117.9		1	
FW1	2005	2001	Kuskokwim R [c]	270	110.2	6.2	2	0.00
FW1	2005	2001	Telaquana Lk	756	94.4	6.1	6	-1.04
FW1	2005	2001	Holitna (Chukowan)	709	93.2		1	
FW1	2005	2001	Hoholitna	538	90.9	3.4	7	0.01
FW1	2005	2001	Holitna [e]	491	88.3	2.0	16	-0.82
FW1	2005	2001	Kogrukluk R	709	86.5	3.3	13	1.09
FW1	2005	2001	Aniak R [d]	307	81.5	2.9	6	0.08
FW1	2005	2001	Stony (Two Lakes)	740	69.6	2.1	3	0.71
FW1	2006	2002	Telaquana Lk	756	110.5	1.7	63	-1.04
FW1	2006	2002	Tuluksak R	192	**97.2**	1.3	78	0.25
FW1	2006	2002	Hoholitna	538	**96.5**	2.1	40	0.24
FW1	2006	2002	George R	446	**95.3**	2.6	32	0.24
FW1	2006	2002	Holitna [e]	491	**94.6**	1.3	86	0.11
FW1	2006	2002	Kwethluk	131	**94.3**	1.4	72	0.16
FW1	2006	2002	Upper Aniak (Salmon)	390	**91.4**	2.2	41	0.68
FW1	2006	2002	Stony R [b]	536	**91.1**	4.9	14	-0.19
FW1	2006	2002	Holokuk/Oskawalik R	380	**90.4**	4.5	10	0.57
FW1	2006	2002	Aniak R [d]	307	**90.2**	1.8	37	0.53
FW1	2006	2002	Kuskokwim R [c]	709	**89.9**	2.1	40	0.29
FW1	2006	2002	Holitna (Chukowan)	709	**89.8**	3.0	20	0.22
FW1	2006	2002	Kogrukluk (Shotgun)	720	**89.1**	3.4	14	0.07
FW1	2006	2002	Kuskokwim R	270	**86.3**	5.5	8	-0.36
FW1	2006	2002	Stony (Two Lakes)	740	**84.8**	3.8	13	0.09

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Table 2.2.–Page 2 of 5.

Life stage	Adult year	Growth year	Location	River km [a]	Length (mm)	SE	n	Skewness
FW1	2007	2003	Telaquana Lk	756	105.8	2.5	28	-0.15
FW1	2007	2003	Kogrukluk (Shotgun)	720	**90.3**	4.1	7	-0.55
FW1	2007	2003	Aniak R [d]	307	**88.8**	1.3	79	0.45
FW1	2007	2003	Holitna [e]	491	**88.1**	1.4	49	-0.17
FW1	2007	2003	Hoholitna	538	**87.8**	1.6	39	0.20
FW1	2007	2003	Kuskokwim R [c]	270	**87.4**	2.2	38	0.01
FW1	2007	2003	Holitna (Chukowan)	709	**87.3**	3.3	18	-0.09
FW1	2007	2003	Stony R [b]	536	**87.3**	8.8	6	0.37
FW1	2007	2003	Kwethluk	131	**84.8**	1.1	139	0.98
FW1	2007	2003	Holokuk/Oskawalik R	380	**84.3**	5.7	4	0.47
FW1	2007	2003	Kogrukluk R	709	**82.6**	1.6	44	0.99
FW1	2007	2003	Stony (Two Lakes)	740	**80.8**	2.8	11	1.34
FW1	2007	2003	Upper Aniak (Salmon)	390	**69.6**	1.0	2	0.00
FW1 & FWPL	2005	2002	Kuskokwim R [c]	270	127.6	11.2	2	0.00
FW1 & FWPL	2005	2002	Telaquana Lk	756	118.8	7.1	6	-0.14
FW1 & FWPL	2005	2002	Stony R [b]	536	117.9		1	
FW1 & FWPL	2005	2002	Kogrukluk R	709	115.4	3.6	13	-0.50
FW1 & FWPL	2005	2002	Stony (Two Lakes)	740	109.0	1.5	3	-0.65
FW1 & FWPL	2005	2002	Holitna [e]	491	101.0	4.8	16	1.19
FW1 & FWPL	2005	2002	Aniak R [d]	307	97.8	7.2	6	0.01
FW1 & FWPL	2005	2002	Hoholitna	538	94.5	4.0	7	-0.18
FW1 & FWPL	2005	2002	Holitna (Chukowan)	709	93.2		1	
FW1 & FWPL	2006	2003	Telaquana Lk	756	116.1	1.4	63	-0.41
FW1 & FWPL	2006	2003	Kwethluk	131	**100.3**	1.9	72	0.59
FW1 & FWPL	2006	2003	Hoholitna	538	**100.0**	2.5	40	0.35
FW1 & FWPL	2006	2003	Tuluksak R	192	**99.3**	1.5	78	0.54
FW1 & FWPL	2006	2003	George R	446	**99.1**	3.1	32	0.59

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Table 2.2.–Page 3 of 5.

Life stage	Adult year	Growth year	Location	River km [a]	Length (mm)	SE	n	Skewness
FW1 & FWPL	2006	2003	Kogrukluk (Shotgun)	720	**98.2**	3.6	14	0.24
FW1 & FWPL	2006	2003	Stony R [b]	536	**98.0**	4.5	14	-0.52
FW1 & FWPL	2006	2003	Holitna [e]	491	**96.8**	1.4	86	0.19
FW1 & FWPL	2006	2003	Kuskokwim R [c]	270	**96.2**	9.2	8	0.40
FW1 & FWPL	2006	2003	Upper Aniak (Salmon)	390	**95.6**	2.4	41	0.37
FW1 & FWPL	2006	2003	Aniak R [d]	307	**95.3**	2.4	37	0.54
FW1 & FWPL	2006	2003	Kogrukluk R	709	**93.3**	2.3	40	0.63
FW1 & FWPL	2006	2003	Stony (Two Lakes)	740	**92.3**	3.5	13	0.78
FW1 & FWPL	2006	2003	Holokuk/Oskawalik R	380	**90.4**	4.5	10	0.57
FW1 & FWPL	2006	2003	Holitna (Chukowan)	709	**89.8**	3.0	20	0.22
FW1 & FWPL	2007	2004	Holokuk/Oskawalik R	380	127.4	7.0	4	-0.13
FW1 & FWPL	2007	2004	Stony R [b]	536	120.9	6.0	6	0.11
FW1 & FWPL	2007	2004	Telaquana Lk	756	119.9	2.8	28	0.60
FW1 & FWPL	2007	2004	Kuskokwim R [c]	270	119.1	2.7	38	0.06
FW1 & FWPL	2007	2004	Kogrukluk (Shotgun)	709	118.4	7.0	7	-1.04
FW1 & FWPL	2007	2004	Holitna [e]	491	115.5	2.7	49	0.08
FW1 & FWPL	2007	2004	Stony (Two Lakes)	740	114.3	4.0	11	0.36
FW1 & FWPL	2007	2004	Kwethluk	131	**112.5**	1.4	139	-0.46
FW1 & FWPL	2007	2004	Holitna (Chukowan)	709	111.6	3.9	18	0.51
FW1 & FWPL	2007	2004	Aniak R [d]	307	**110.0**	2.2	79	0.05
FW1 & FWPL	2007	2004	Hoholitna	538	**109.7**	2.6	39	0.01
FW1 & FWPL	2007	2004	Kogrukluk R	709	**109.0**	3.0	44	-0.26
FW1 & FWPL	2007	2004	Upper Aniak (Salmon)	390	98.2	5.9	2	0.00
FWPL	2005	2002	Stony (Two Lakes)	740	39.4	3.5	3	-0.70
FWPL	2005	2002	Kuskokwim R [c]	709	29.0	5.0	13	-0.68

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Table 2.2.–Page 4 of 5.

Life stage	Adult year	Growth year	Location	River km [a]	Length (mm)	SE	n	Skewness
FWPL	2005	2002	Telaquana Lk	756	24.4	11.8	6	0.46
FWPL	2005	2002	Kuskokwim R	270	17.5	17.5	2	0.00
FWPL	2005	2002	Aniak R	307	16.4	7.7	6	0.30
FWPL	2005	2002	Holitna [e]	491	12.7	5.0	16	0.97
FWPL	2005	2002	Hoholitna	538	3.5	3.5	7	2.04
FWPL	2005	2002	Holitna (Chukowan)	709	0.0		1	
FWPL	2005	2002	Stony R [b]	536	0.0		1	
FWPL	2006	2003	Kuskokwim R [c]	270	9.9	6.5	8	1.19
FWPL	2006	2003	Kogrukluk (Shotgun)	720	9.1	4.9	14	1.42
FWPL	2006	2003	Stony (Two Lakes)	740	7.5	4.1	13	1.59
FWPL	2006	2003	Stony R [b]	536	6.9	3.7	14	1.53
FWPL	2006	2003	Kwethluk	131	6.0	1.5	72	1.87
FWPL	2006	2003	Telaquana Lk	756	5.6	1.6	63	1.89
FWPL	2006	2003	Aniak R [d]	307	5.1	2.0	37	2.07
FWPL	2006	2003	Upper Aniak (Salmon)	390	4.2	1.6	41	2.21
FWPL	2006	2003	George R	446	3.9	1.7	32	2.14
FWPL	2006	2003	Hoholitna	538	3.5	1.7	40	2.91
FWPL	2006	2003	Kogrukluk R	709	3.4	1.7	40	3.11
FWPL	2006	2003	Holitna [e]	491	2.3	0.9	86	3.44
FWPL	2006	2003	Tuluksak R	192	2.1	1.1	78	4.16
FWPL	2006	2003	Holitna (Chukowan)	709	0.0	0.0	20	
FWPL	2006	2003	Holokuk/Oskawalik R	380	0.0	0.0	10	
FWPL	2007	2004	Holokuk/Oskawalik R	380	**43.0**	3.2	4	0.31
FWPL	2007	2004	Stony R [b]	538	**33.6**	12.2	6	0.07
FWPL	2007	2004	Stony (Two Lakes)	740	**33.6**	2.5	11	-0.56
FWPL	2007	2004	Kuskokwim R [c]	270	**31.7**	3.2	38	-0.11
FWPL	2007	2004	Upper Aniak (Salmon)	390	28.6	5.0	2	0.00
FWPL	2007	2004	Kogrukluk (Shotgun)	720	28.1	8.5	7	-0.04

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Table 2.2.–Page 5 of 5.

Life stage	Adult year	Growth year	Location	River km [a]	Length (mm)	SE	n	Skewness
FWPL	2007	2004	Kwethluk	131	**27.7**	1.8	139	-0.13
FWPL	2007	2004	Holitna [e]	491	**27.4**	3.0	49	0.01
FWPL	2007	2004	Kogrukluk R	709	**26.5**	3.3	44	0.04
FWPL	2007	2004	Holitna (Chukowan)	709	24.3	5.8	18	0.30
FWPL	2007	2004	Hoholitna	538	21.9	3.1	39	0.18
FWPL	2007	2004	Aniak R [d]	307	21.2	2.2	79	0.24
FWPL	2007	2004	Telaquana Lk	756	14.1	3.8	28	1.11

Note: Values that were significantly different (P <0.05) from the value in the box from the same life stage and year (e.g., Telequana Lake) are highlighted in bold. Values are shown in descending order within each life stage and year. The "Kuskokwim River" group represented a mixture of tagged fish sockeye salmon for which tributary / habitat could not be determined.

[a] Distance from the mouth of the Kuskokwim River to the mouth of the spawning tributary.

[b] Includes entire Stony River drainage except the associated lake systems (i.e., Telaquana Lk and Stony (Two Lakes)).

[c] Kuskokwim R location represents all sockeye salmon that were not tracked to a spawning tributary. River kilometer provided is consistent with the location of tagging. Spawning activity in the mainstem was not confirmed.

[d] Includes entire Aniak River drainage except the Upper Aniak (Salmon).

[e] Includes entire Holitna River drainage except the Hoholitna, Kogrukluk R, Kogrukluk (Shotgun) and Holitna (Chukowan).

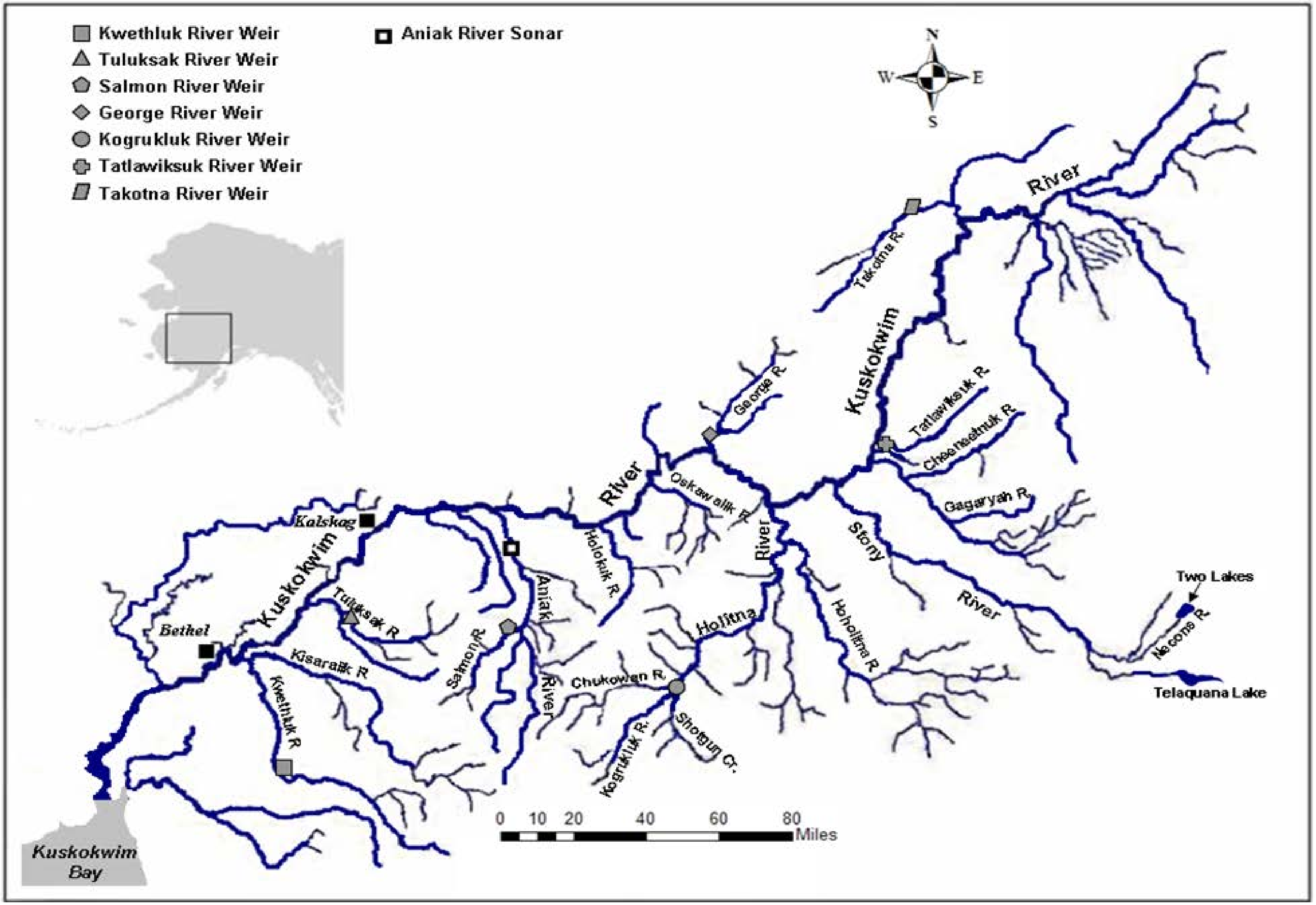
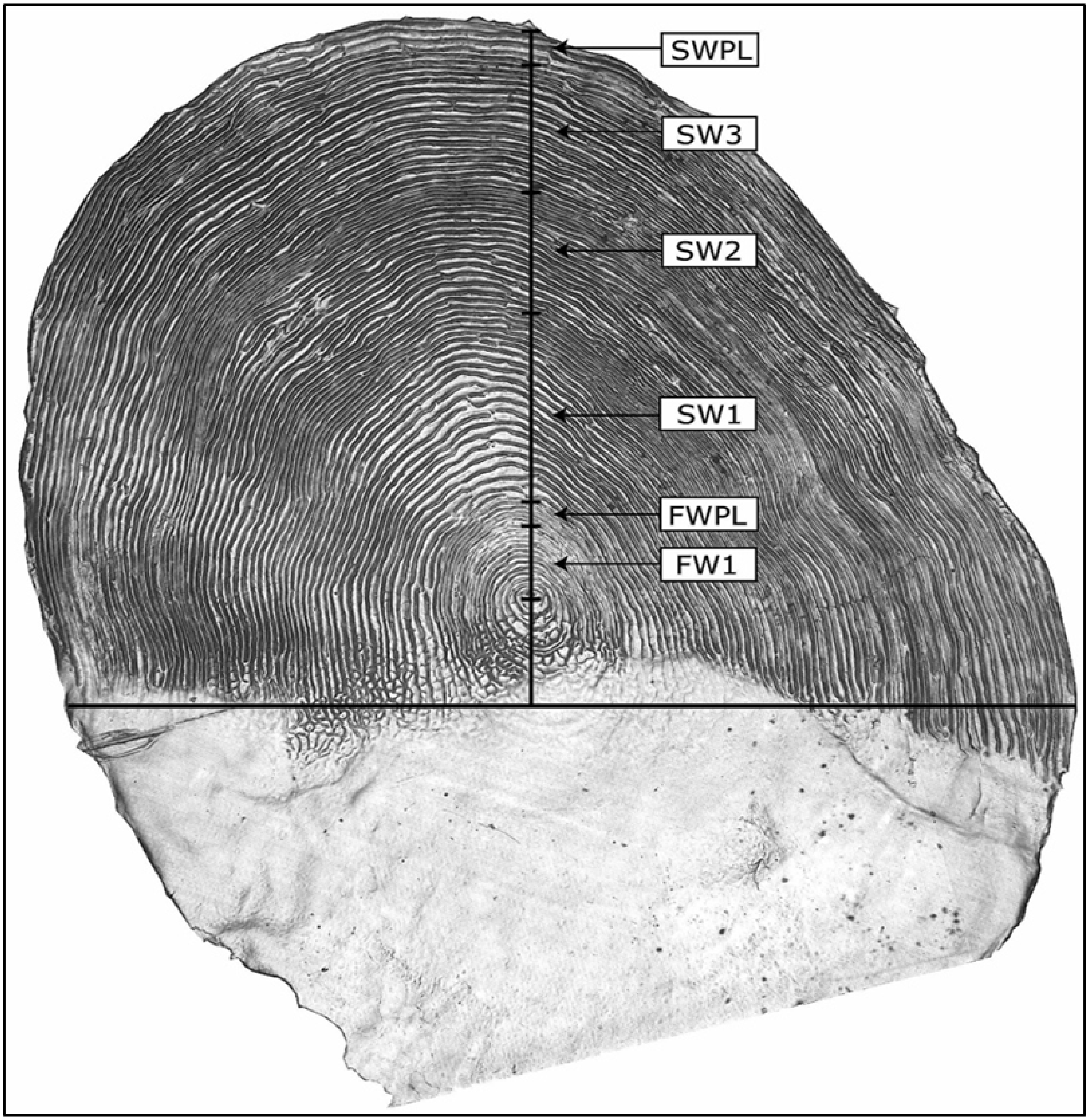


Figure 2.1.–Kuskokwim River watershed with location of major tributaries, adult salmon weirs, and Kalskag tagging location.



Source: Ruggerone et al. 2007

Figure 2.2.–Age-1.3 sockeye salmon scale showing the perpendicular measurement axis and the life stage zones corresponding to growth during the first year in freshwater (FW1), spring growth during the year of smoltification (FWPL), growth during each year at sea (SW1, SW2, SW3), and growth during the homeward migration (SWPL).

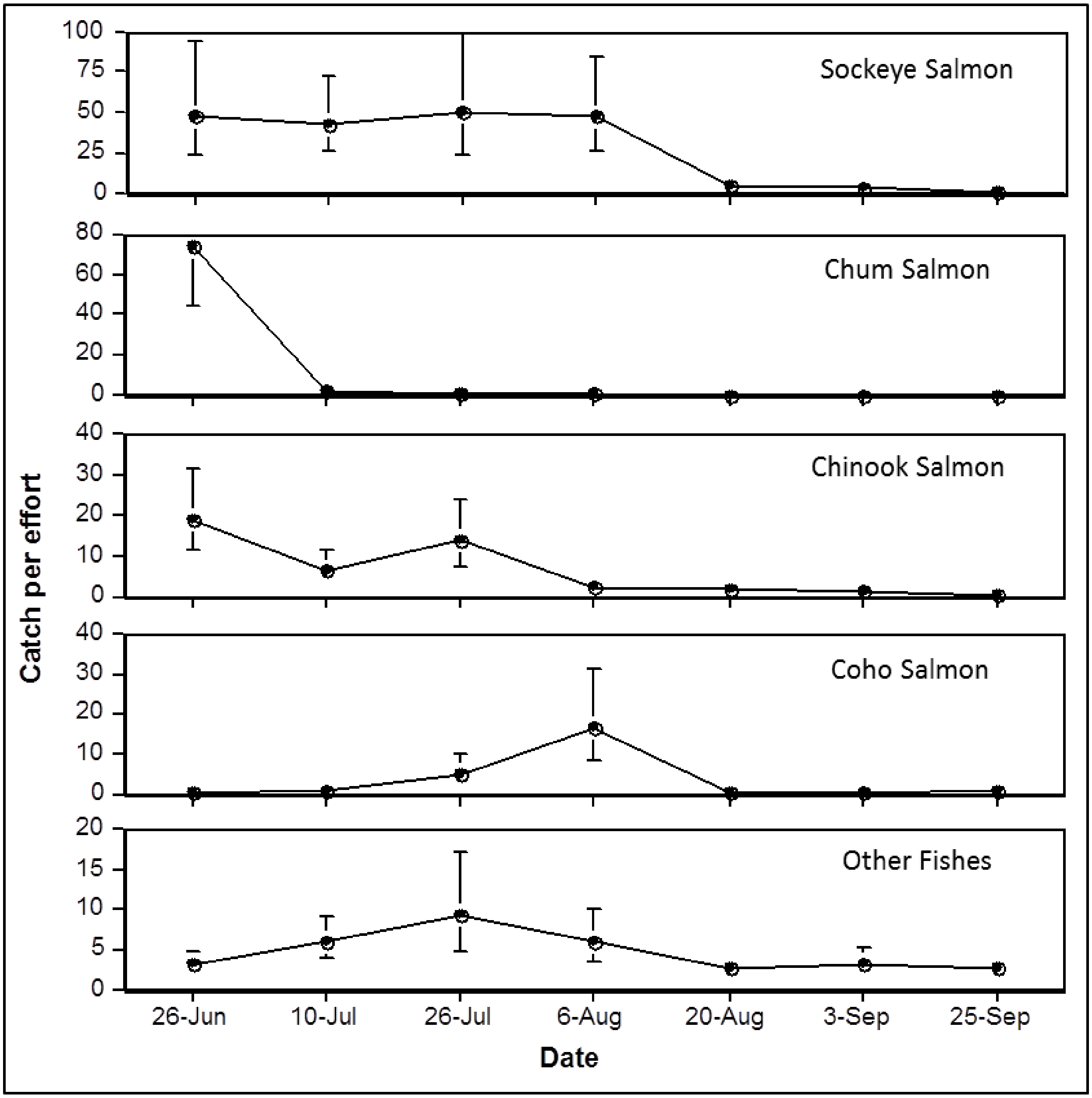


Figure 2.3.–Geometric mean beach seine catch (±1 SE) of age-0 salmon and other fishes in the upper Holitna River (Kogrukluk R) during late June to late September, 2006.

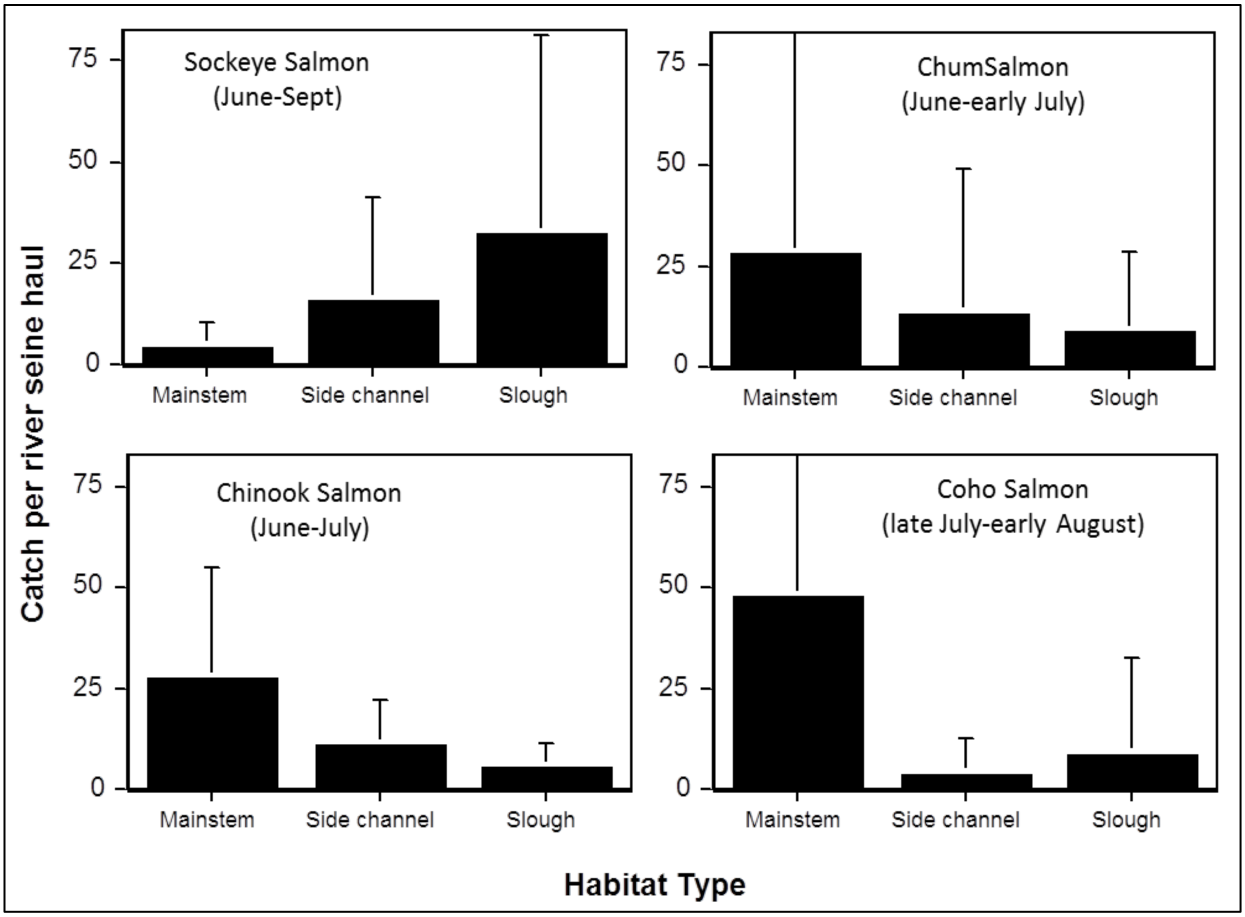


Figure 2.4.–Geometric mean catch per river seine haul of age-0 salmon the upper Holitna River (Kogrukluk R) during 2006.

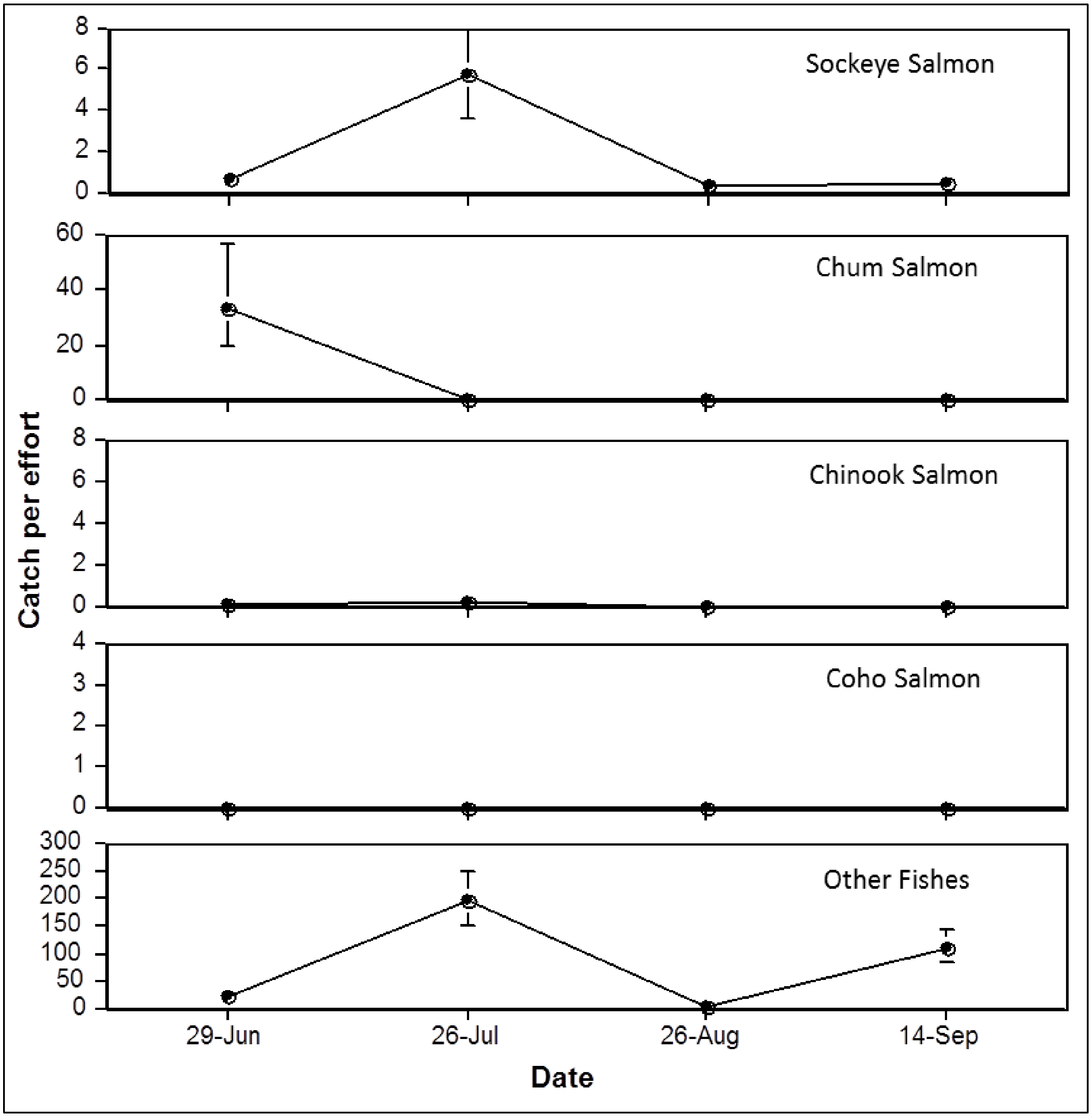


Figure 2.5.–Geometric mean beach seine catch (±1 SE) of age-0 salmon and total non-salmonids in the lower Holitna River during late June to late September, 2006.

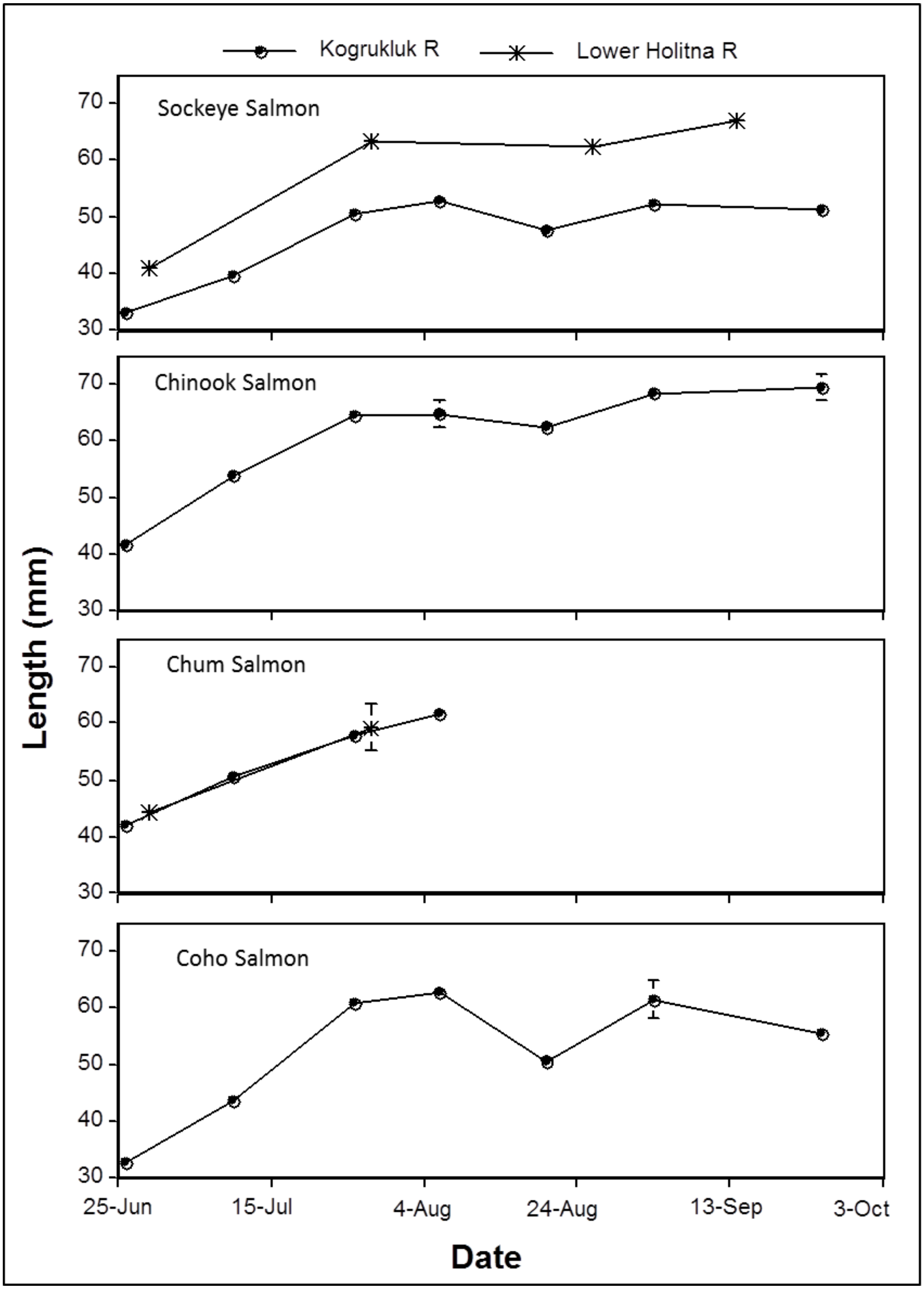
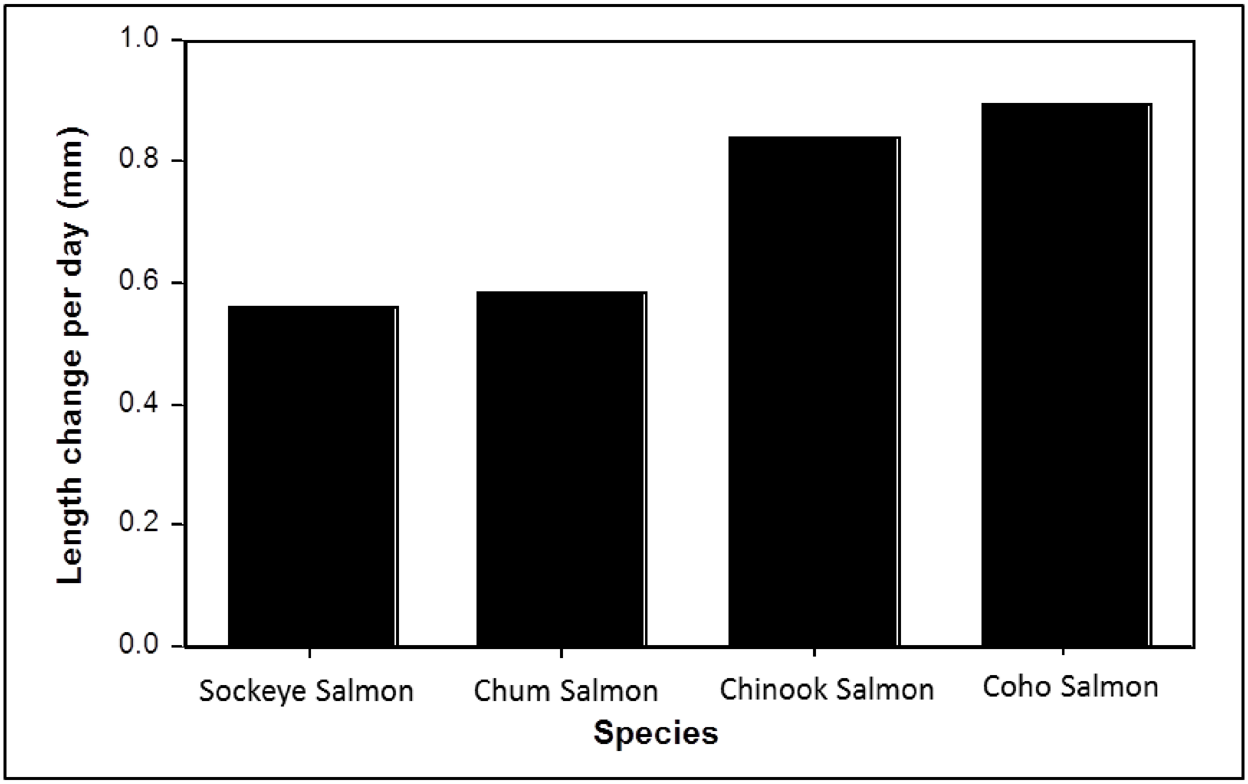


Figure 2.6.–Mean live length (±1 SE) of age-0 salmon in the upper and lower Holitna River from late June to late September, 2006.



Note: Values are based on change in mean length during the period when change was relatively consistent and catch rates were relatively high. Values reflect growth and movement of individuals into and out of the study area.

Figure 2.7.–Approximate mean growth per day of juvenile salmon in the upper Holitna River (Kogrukluk R) during June and July 2006.

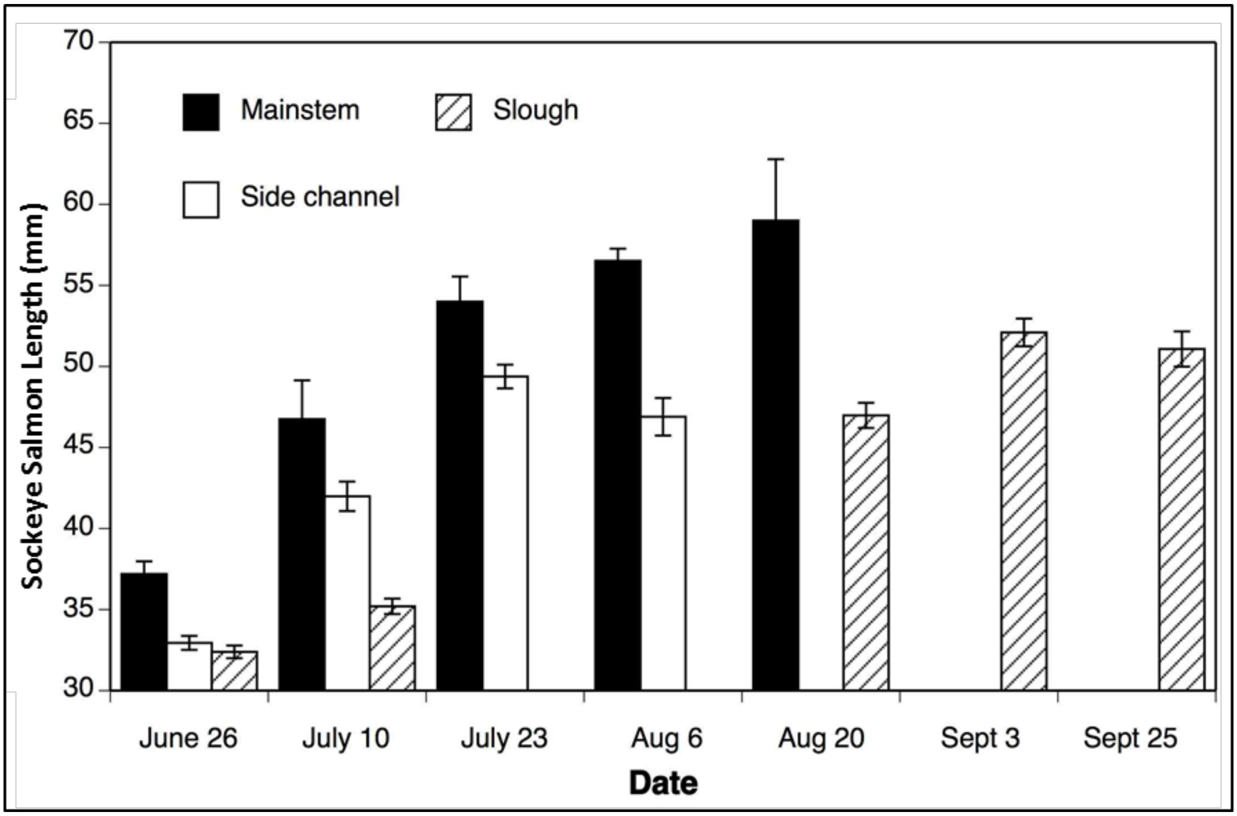
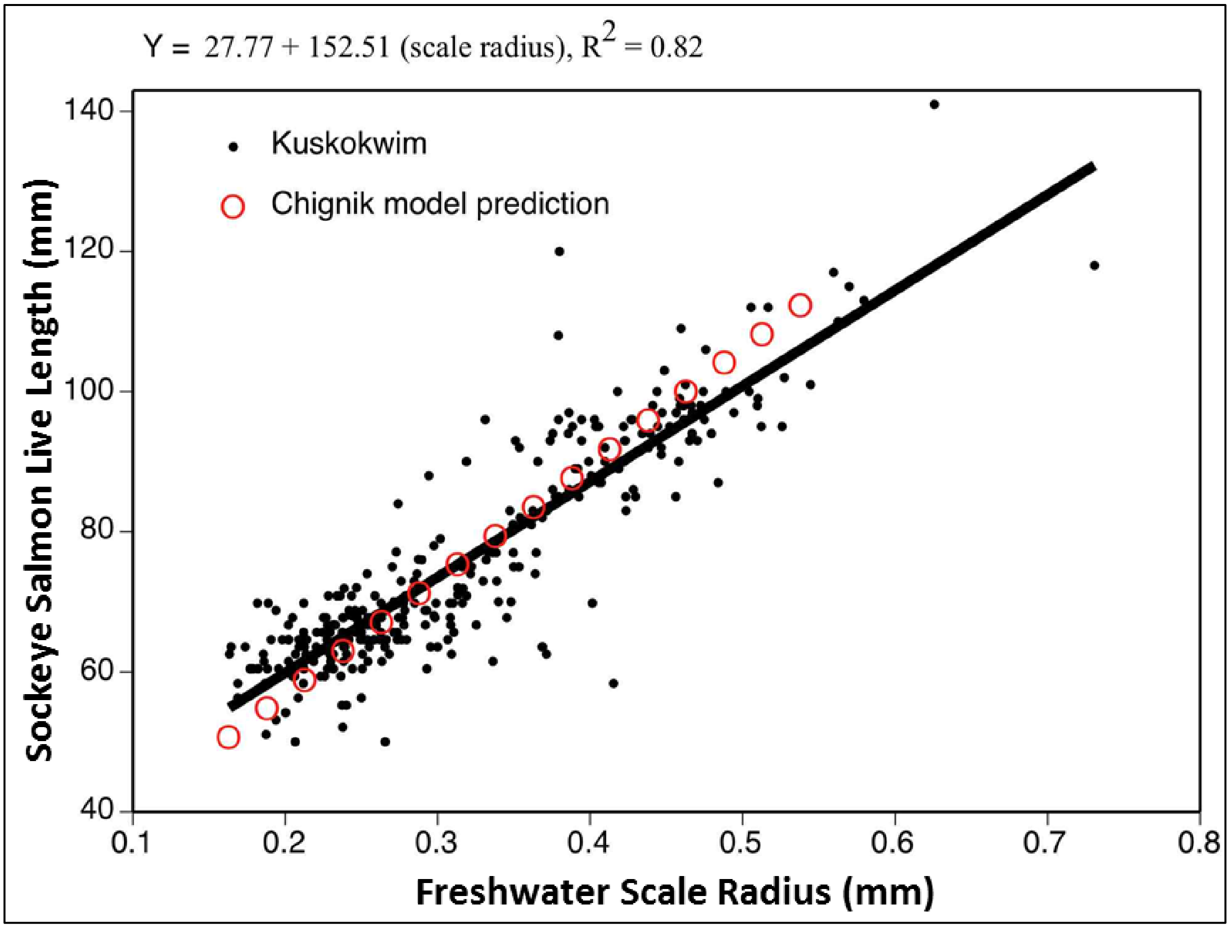
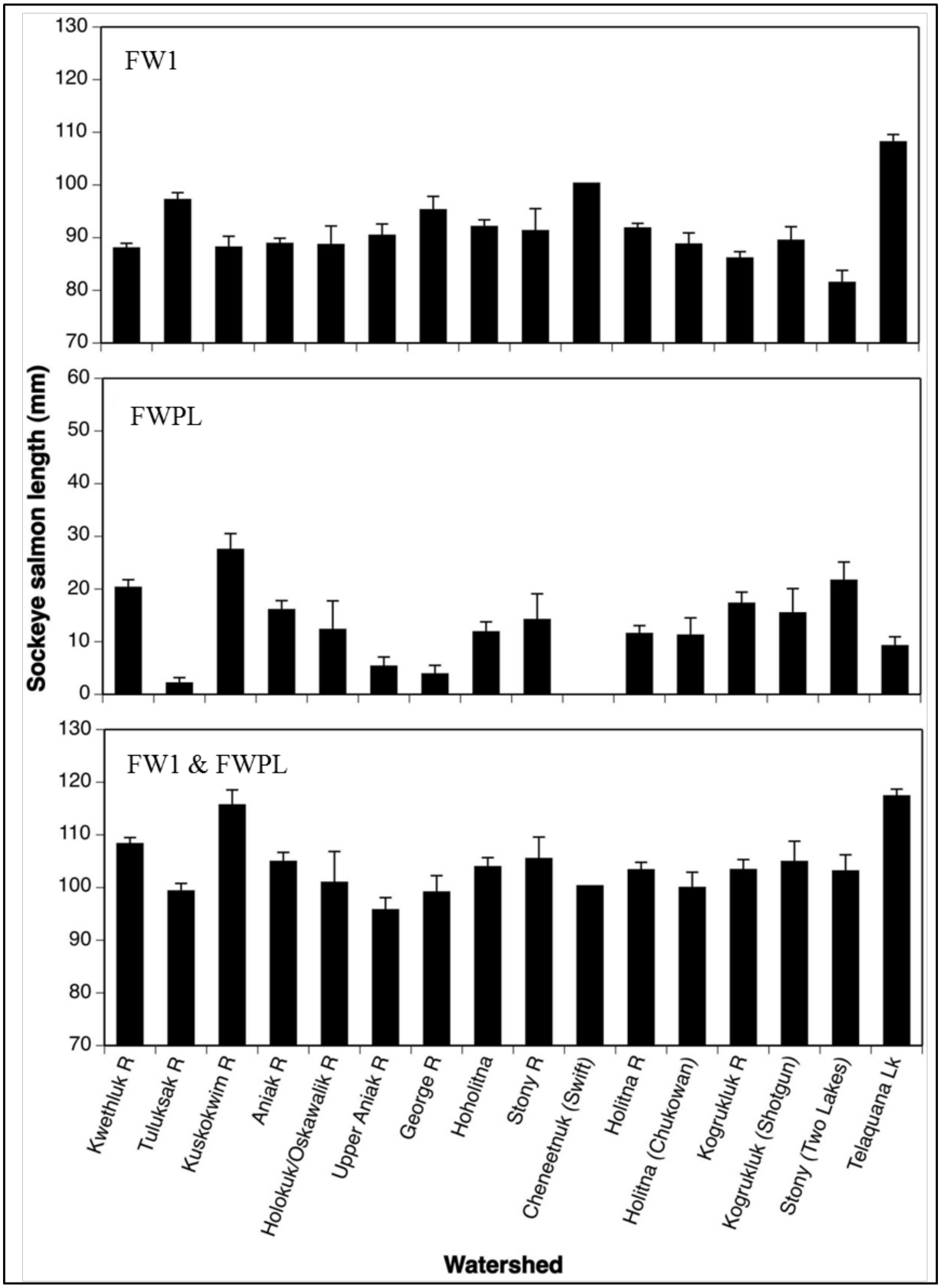


Figure 2.8.–Mean length mean (±1 SE) of subyearling sockeye salmon captured in mainstem, side channel, and slough habitats of the upper Holitna River (Kogrukluk R) during late June through September 2006.



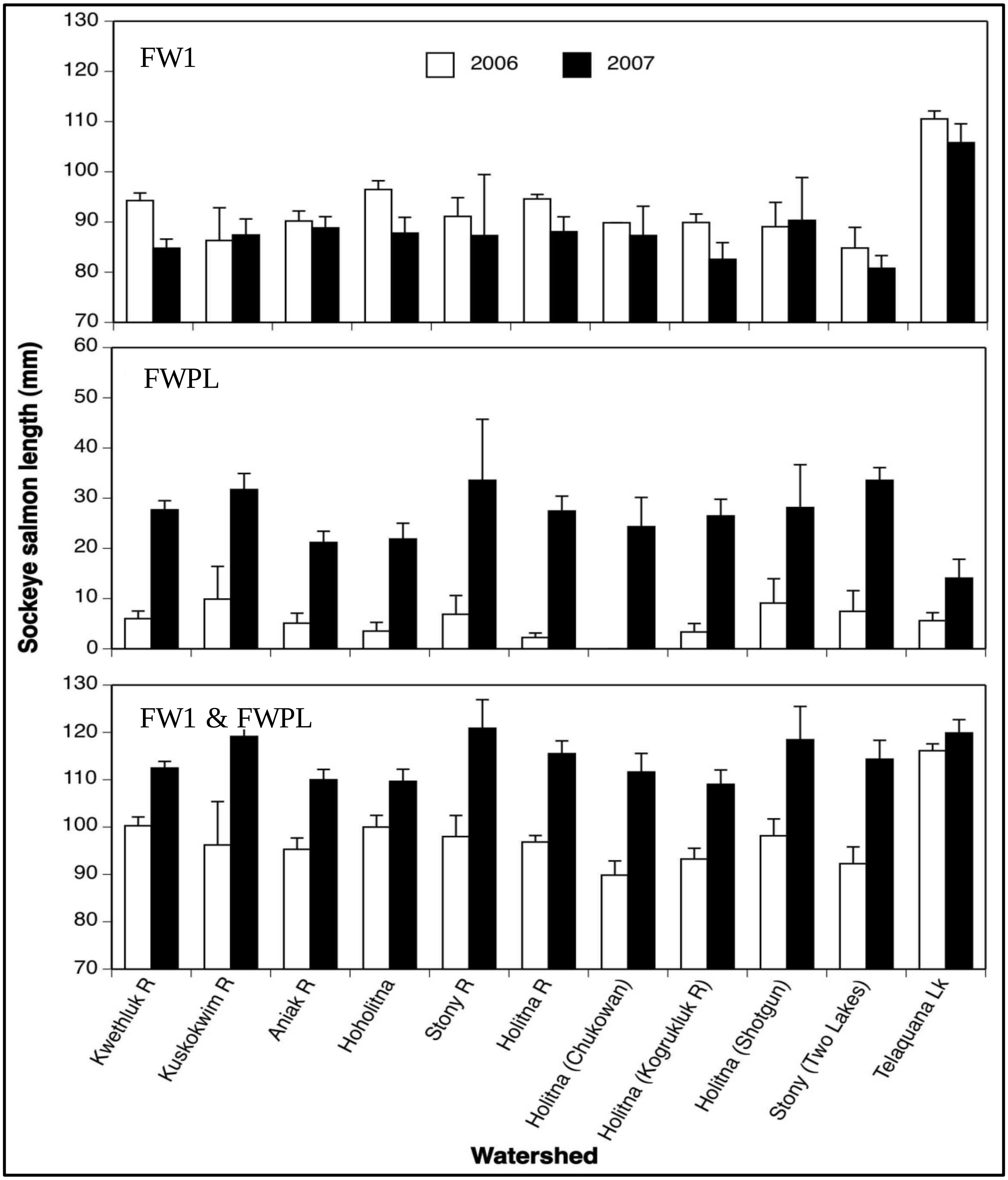
Note: The geometric mean regression for juvenile sockeye salmon from the Chignik watershed, Alaska, is shown for comparison.

Figure 2.9.–Geometric mean regression of juvenile Kuskokwim River sockeye salmon back calculated length on their freshwater scale radius (FW1 & FWPL).



Note: Values include all data from adult return years 2005, 2006, and 2007. The "Kuskokwim River" group represented a mixture of tagged fish sockeye salmon for which tributary / habitat could not be determined.

Figure 2.10.–Mean (±1 SE) back-calculated length of sockeye salmon from areas within the Kuskokwim River drainage at the end of the first growing season, and the end of the smolt transition period during the following spring, and the incremental growth during the smolt period.



Note: Watersheds having few scales or scales during only one year were excluded. The "Kuskokwim River" group represented a mixture of tagged fish sockeye salmon for which tributary / habitat could not be determined.

Figure 2.11.–Comparison of mean (±1 SE) back-calculated length of sockeye salmon from each area and life stage in the Kuskokwim River drainage during adult return years 2006 versus 2007.

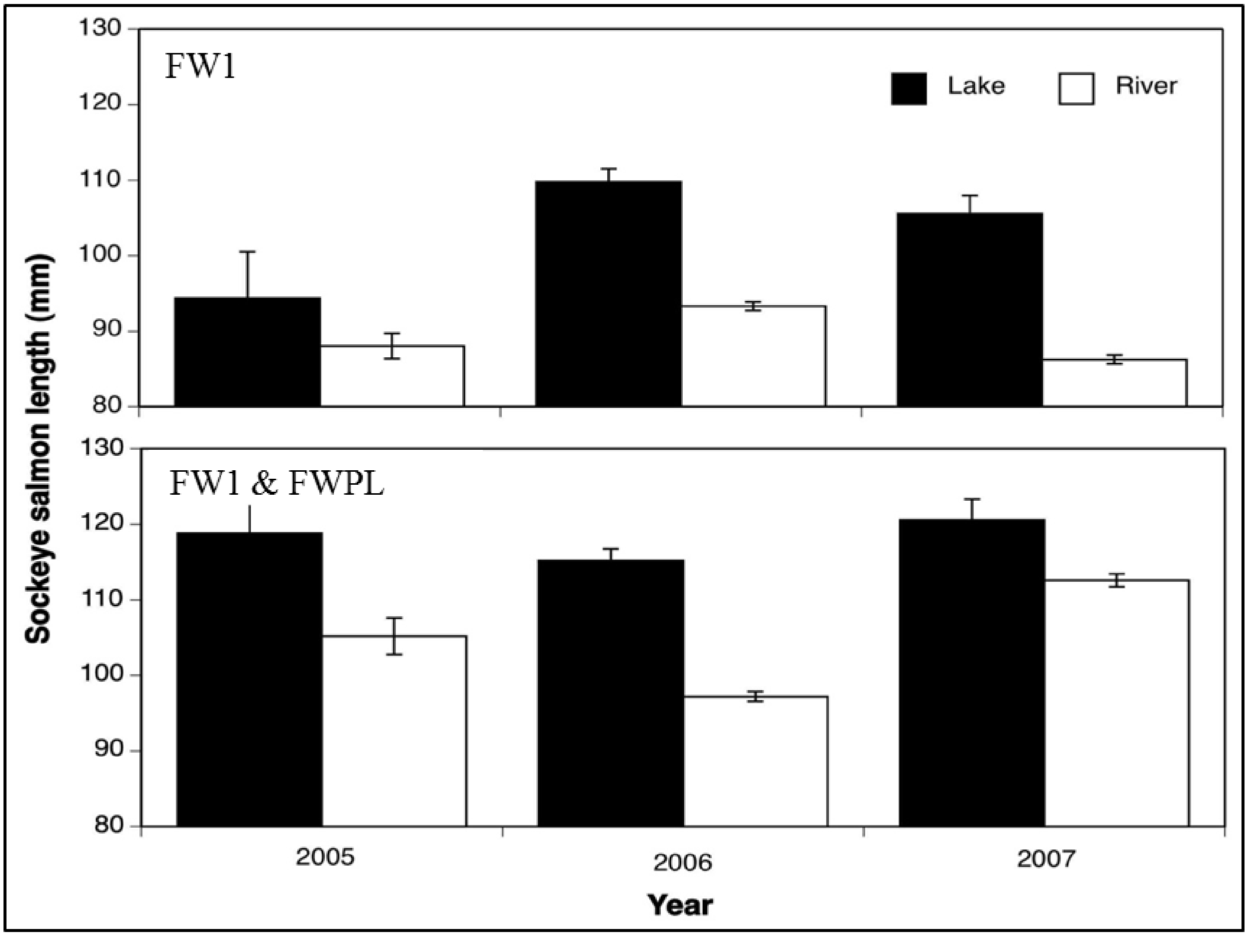


Figure 2.12.–Comparison of back-calculated mean length (±1 SE) of river- versus lake-rearing sockeye salmon during each life stage, adult years 2005–2007.

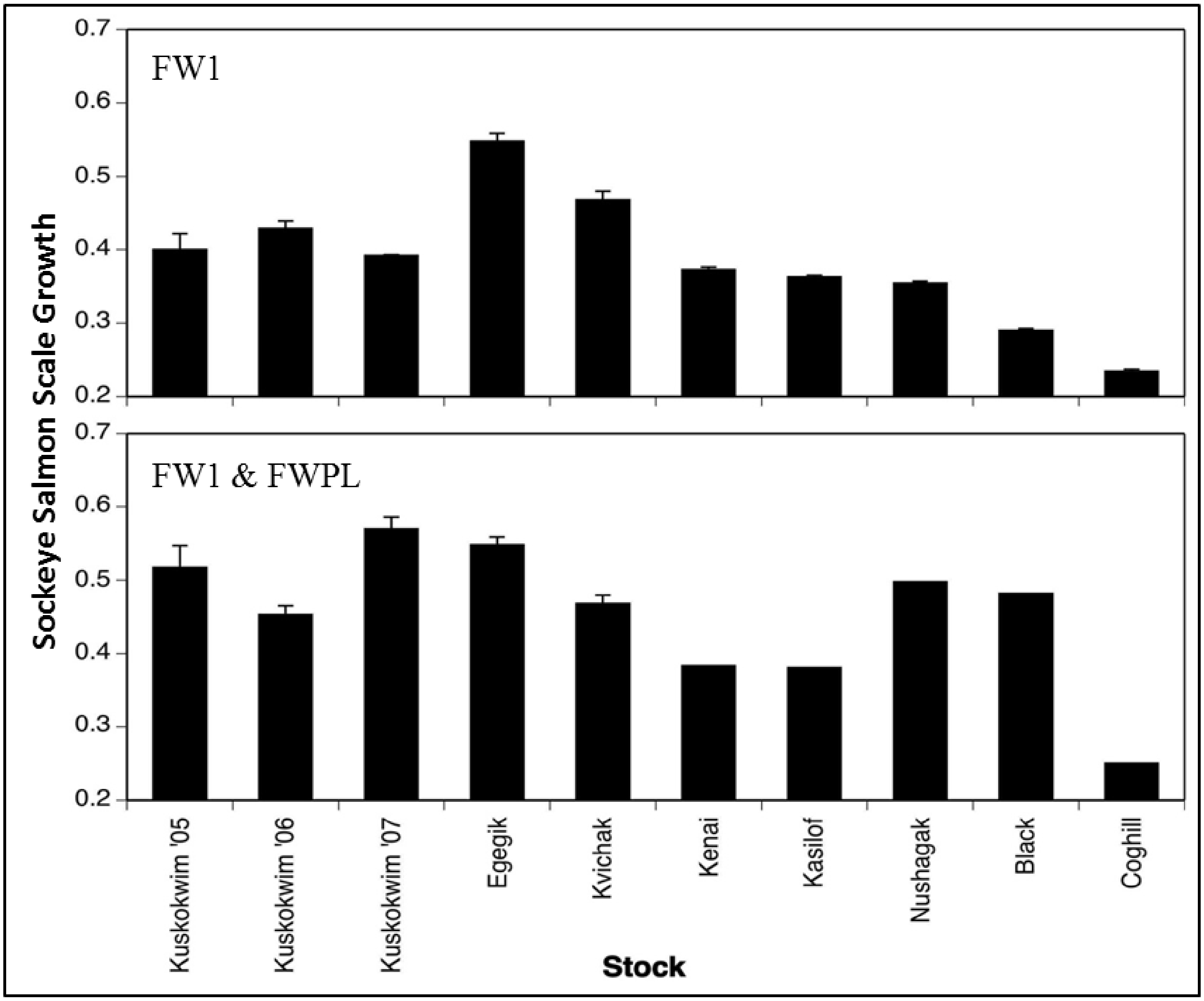


Figure 2.13.–Comparison of mean (±1 SE) of sockeye salmon scale growth in the Kuskokwim River (adult return years 2005–2006) versus age-1.3 lake-rearing sockeye salmon from other regions of Alaska (Ruggerone and Rogers 1998).

APPENDIX 2.A: PHOTOGRAPHS OF FISH SAMPLING AND HABITAT

Appendix Figure 2.A.1.–Setting the river seine along the mainstem (top) and slough (bottom) of the Kogrukluk River.

Appendix Figure 2.A.2.–Examples of slough habitat in the Kogrukluk River.

Appendix Figure 2.A.3.–Setting the river seine in the lower Holitna River.

Appendix Figure 2.A.4.–Chum (upper) and sockeye (lower) salmon fry.

CHAPTER 3. OUTREACH AND CAPACITY BUILDING ASSOCIATED WITH THE KUSKOKWIM RIVER SOCKEYE SALMON INVESTIGATIONS

by

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ABSTRACT

During the Kuskokwim Sockeye Salmon Investigation study we developed and implemented an outreach and capacity building plan that was nested within several other more long-term programs. We communicated with the Kuskokwim River Salmon Management Working Group and communities closest to the field research activities focusing on listening as well as informing (two-way communication). We informed the Kuskokwim area general public about this research and applications to management using mass media including newspaper articles, press releases, and radio programs. We taught lessons in village school classrooms about the basics of fisheries science and management to encourage students to pursue fisheries careers and to become involved citizens. We hired several local residents in fisheries technician and intern positions and supported their professional development. Through these activities and processes we focused on building the capacity of all organizations and people involved by learning and teaching one-another and institutionalizing the knowledge and capabilities gained. As a result of these outreach and capacity building efforts, local input was included into the study, relationships were built and strengthened, and communities and the public were better informed about research. Ultimately, this lead to stronger community and general public support for this study and strengthened a foundation of capacity that will hopefully lead to a future of increased cooperation among local residents, rural organizations, and fisheries management agencies.

Key words: capacity building; outreach, education; public involvement; Kuskokwim River; cooperative research

INTRODUCTION

Local involvement can substantially benefit fisheries research and management and it can be an effective tool to guide management decisions and increase community acceptance of those decisions. Historically, however, local residents have often been inadequately informed and involved with fishery management and research in the Kuskokwim Area, which resulted in public distrust of agencies, a lack of public acceptance of agency actions, and squandering of resources (e.g., Appendix 3.A). Public distrust was a strong influence in formation of the Kuskokwim River Salmon Management Working Group in 1988, which is a collection of stakeholders recognized by the Alaska Board of Fisheries as a formal advisory group to the Alaska Department of Fish and Game. This effort along with other similar efforts during the past two decades has been part of a strong statewide movement of agencies and local people working more closely together. Despite this recent success, often the avenues to communicate and work together are not fully developed. Rural organizations and communities may lack the capacity to be effective and independent partners, and agencies may lack the capacity to fully incorporate local involvement. Therefore, the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYKSSI), primary funding organization of the Kuskokwim sockeye salmon investigation study, requested as part of the study design an outreach and capacity building plan (AYKSSI 2005). This chapter is a description of the outreach and capacity building efforts and the associated results of those efforts.

BACKGROUND

The concept of outreach can be obscure and researchers have interpreted it in many ways. The AYKSSI steering committee also realized that the concept of capacity building in Alaska fisheries management is ambiguous and that little consensus exists about the appropriate tools and approaches (AYKSSI 2006). In fact, the concept of capacity building in many disciplines throughout the world is complicated and ambiguous (Cannon et al. 2005).

There are several definitions and interpretations of the concepts of outreach and capacity, but for the purpose of this study and report we used the following definitions:

1. Outreach: *two-way communication between the agency and the public to establish and foster mutual understanding, promote public involvement, and influence behaviors,*

attitudes and actions with the goal of improving the foundations of stewardship. NOAA Fisheries Services Outreach Strategic Plan (NOAA 2007)

2. Capacity: *the ability of individuals and organizations or organizational units to perform functions effectively, efficiently, and sustainably*. United Nations Development Program (1997) adopted by the AYKSSI Steering Committee (AYKSSI 2006)
3. Capacity Building: *the process by which individuals, groups, organizations, institutions and societies increase their abilities to perform functions, solve problems, and achieve objectives; to understand and deal with their development need in a broader context and in a sustainable manner*. United Nations Development Program (Cannon et al. 2005; UNDP 1997)

Outreach comes in many varieties and can include tenants of congressional, corporate, media, non-governmental organization, and government agency relations (NOAA 2007). However, for the purpose of this report we will focus on public outreach which includes public involvement, public information, public education, and public informational products. Public outreach efforts have two main forms distinguished by the level of public participation. Education or information outreach is focused on delivering a message and increasing the public's awareness and understanding of an issue or project. Public input in this type of outreach is usually collected informally and as a secondary goal. Public participation outreach is focused on collecting public input, usually in a formal manner, to include research and management.

Capacity building is essentially facilitating the change of human behavior on the individual, organizational, or societal level, and is deeply rooted in the field of applied social science. It is ambiguous, uncertain, and complex and there are usually multiple interacting causes for any particular result (Cannon et al. 2005). However, many general themes of successful capacity building programs are available in the literature (Taylor and Clarke 2008; Cannon et al. 2005; Schacter 2000; Land 1999; Morgan 1999; UNDP 1997). Most successful capacity building efforts have the following characteristics:

1. Are evaluative rather than descriptive (i.e., focus on how well the efforts are doing rather than what the efforts are) and use evaluation to promote learning, continual feedback, and adaptation—instead of pursuing attractive methods that may be ineffective (e.g., methods that are easy to understand and implement but do not work, or "pet" methods that are untested).
2. Focus on capacity building as a continuous, iterative process and how well individuals, organizations, or societies perform and support learning—rather than specific, short-term technical outputs.
3. Integrate all levels of capacity building including the individual, organization, and the greater society and focus on encouraging transfer of capacity among these levels.
4. Account for the realities of context specific factors including politics, economics, and culture.
5. Incorporate a strong element of local control and initiative.
6. Balance bottom-up and top-down accountability to ensure that both funding entities' or mentors' desires and recipients' desires are accounted for and included into efforts.
7. Focus on the long-term process and how the individual study will contribute to the long-term capacity building goals—the United Nations suggest that 10 years is an appropriate length of time to implement capacity building programs.

OBJECTIVES

1. Include public participation in research with a focus on the Kuskokwim River Salmon Management Working Group;
2. Communicate with communities closest to field research sites about field research activities in their area;
3. Communicate with the Kuskokwim area general public about research methods, applicability to sustainable fisheries management, and results;
4. Teach Kuskokwim youth about fisheries ecology, science, and management;
5. Employ rural Alaskan residents in fisheries research;
6. Build the capacity of the Kuskokwim Native Association and Association of Village Council Presidents (AVCP) in fisheries research; and
7. Build the capacity of the Kuskokwim Area ADF&G Commercial Fisheries Division in community outreach and partnerships with rural Native organizations.

METHODS, RESULTS, AND DISCUSSION

PUBLIC PARTICIPATION IN RESEARCH

The Kuskokwim River Salmon Management Working Group (KRSMWG) is an advisory group composed of representatives from commercial, sport, and subsistence users from throughout the river. They typically meet one or more times per week during the summer fishing season, and once or twice in the post- or preseason (Shelden and Linderman 2007). The KRSWG is an exemplary public participation process and has been working with the Kuskokwim Area ADF&G Commercial Fisheries Division since 1988 (Shelden and Linderman 2007). By nesting our community participation outreach into this existing process we were able to communicate with a wider range of local stakeholders prior to, during, and after the sockeye salmon investigation study as suggested by others (AYKSSI 2006; Cannon et al. 2005; Meffe et al. 2002). Members were introduced to the sockeye salmon investigation project through brief oral updates during summer meetings and through more detailed presentations and discussions at pre and postseason meetings. Input from members was discussed and considered throughout the development and implementation of the sockeye salmon investigation project. The regularity and open forum of the KRSMWG meetings allowed researchers and members to continually communicate about this study and learn together as the study progressed, which is preferred over the traditional form of the researchers coming back to public to present results after the project has been completed (Meffe et al. 2002).

COMMUNICATION WITH AFFECTED COMMUNITIES

The communities of Lower Kalskag, Kalskag, and Aniak are closest in proximity to the tagging site used in the sockeye salmon investigation (see Chapter 1 for details). We described details of project plans to tribal leaders from these communities at the KNA annual Tribal Gathering that was held January 2006 in Aniak. Most of the attendees were already familiar with the associated field activities because of similar projects from previous years that used the same tagging platform (e.g., Stuby 2007; Pawluk et al. 2006).

The community of Sleetmute is closest to the lower Holitna River where researchers planned to operate part of the juvenile salmon habitat usage component of the sockeye salmon investigation (see Chapter 2 for details). Prior to the field activities, we contacted community leaders by phone, discussed what was planned, and solicited input. We also worked with the Sleetmute Traditional Council and arranged a community meeting in June, 2006, where we presented a slideshow and discussed field research activities to a broad range of residents.

COMMUNICATION WITH GENERAL PUBLIC

In addition to meetings in communities nearest to where research activities were occurring, we made efforts to reach out more broadly through use of local newspapers and radio stations and gave presentations at various regional and tribal meetings. A newspaper article, entitled "Kuskokwim River Sockeye Salmon: Secrets Revealed," described the study methods, relevance to management, and preliminary results of the sockeye salmon investigation (Appendix 3.B). The article was published in August 2006, in the Delta Discover Newspaper (Bethel, Alaska) and posted on the ADF&G website news series, Alaska Fish and Wildlife News (http://www.wildlife.alaska.gov/index.cfm?adfg=wildlife_news.view_article&issue_id=44&articles_id=251). Also, an interview with Doug Molyneaux, ADF&G Kuskokwim River Fisheries Research Biologist, aired in August 2006 on KYUK (Bethel, Alaska public radio station). During the KYUK interview, Molyneaux discussed with news reporter Kenny Steele methods relevant to sustainable fisheries management and preliminary study results.

We also presented study summaries at several regional meetings: Yukon-Kuskokwim Delta Federal Regional Advisory Council; Western Interior Federal Regional Advisory Council; KNA Annual Tribal Gathering; and ADF&G Central Kuskokwim Advisory Committee (Table 3.1). The presentations were generally 15 to 20 minute computer slideshows covering several Kuskokwim Area fisheries projects followed by questions and answers and handouts of project summaries. Ten meetings were initiated in coordination with Tribal councils and village schools in Kuskokwim Area communities (Table 3.2). Meeting announcements were distributed to post offices, Tribal council offices, and various local businesses, plus personal invitations were made to key community leaders. In some instances, independent entities donated door prizes that were advertised and offered to those attending the meetings. Turnout at these meetings was variable, ranging from 2 to 15 people per meeting. Typically, these meetings lasted about two hours and included handouts of project summaries and slideshow presentations with intermittent discussions. Presenters covered several Kuskokwim Area projects at each meeting and spent approximately 5 to 10 minutes on each project. We encouraged questions, discussions, and feedback and adapted the meeting to best address the topics that people desired to discuss. In general, meeting attendants' comments on post-meeting questionnaires indicated that as a result of the meetings they had a better understanding of fisheries research and a better appreciation for how research aides fisheries management.

We used multiple methods to inform the public about the Kuskokwim sockeye salmon investigation as suggested by others (Meffe et al. 2002), recognizing the need to balance our efforts within budget and staffing restraints. Building relationships and trust by face-to-face communication is often the key to communicating the sometimes complex messages of fisheries research and management (this is even more apparent in Rural Alaska). However, using mass media outlets such as the Delta Discovery newspaper and the KYUK radio station provided us an avenue to effectively extend outreach to a broader audience than was possible using face-to-face communication alone.

YOUTH EDUCATION

We visited schools 28 times from March 1, 2006 through April 30, 2008 (Table 3.3) and taught Kuskokwim youth about fisheries ecology, science, and management by teaching lessons in their classrooms (see Orabutt and Thalhauser 2008 for more information). We coordinated school visits with community meetings to most efficiently use travel funds and also so that the combined efforts would create a presence in the community. Specific lessons included fisheries careers, local fish species and their life cycles, Kuskokwim fisheries research and monitoring projects, fisheries science techniques such as radiotelemetry, fish anatomy, fish adaptations, fish habitat, stream ecology, and aquatic macroinvertabrates. We used a variety of teaching methods such as slideshows, wet labs, equipment demonstrations, worksheets, games, and hands-on projects. We adjusted the lessons to be age specific and taught kindergarten through twelfth grade students. We requested and received informal feedback from teachers and adjusted lessons accordingly. Teachers indicated that as a result of our school programs their students had a better appreciation for and understanding of fisheries ecology, science, and management. Many teachers also requested that we expand our program in the schools and teach additional lessons.

Children will be the future adult citizens and are still developing core beliefs and attitudes which will affect their life-long behavior of civic involvement. K–12 outreach is a great opportunity for fisheries researchers to help build long-term community capacity and to encourage future participation in fisheries research and management. To participate in a social system such as fisheries management, students need what some educators term a “literacy” of the social system which is to both possess an understanding of the issues, ability to critically think (i.e., apply knowledge to solve real world problems), and the self-confidence to participate (Spirn 2005; Freire and Macedo 1987). This type of knowledge most often comes from students working on real-world problems; still, a close surrogate is for students to work in a mostly independent manor on realistic lessons that have a local setting. Several teachers throughout this project have requested such lessons based on local fisheries research (personal communication Kuspuk School District Science Curriculum Committee; personal communication Linda Cassasas, Kuspuk School District). This type of outreach should be the focus of future efforts associated with Kuskokwim fisheries research projects.

EMPLOYMENT OF RURAL ALASKAN RESIDENTS

We employed three Kuskokwim residents as fisheries technicians to assist with field work associated with the sockeye salmon investigation and to provide ADF&G staff and project leaders with a local perspective on research activities. In addition, we employed ten college interns from Kuskokwim area communities by pooling funds available through the sockeye salmon investigation project with funding from the Partners for Fisheries Monitoring Program (see Orabutt and Thalhauser 2008 for further details). The main goal of the college internship program was to mentor students pursuing fisheries careers. However, we considered in our applicant pool those students with interests in careers outside fisheries, recognizing the experience gained by these future teachers and community leaders can also reap benefits as they become involved in public processes such as the Kuskokwim River Salmon Management Working Group or one of the other public advisory groups. These college interns worked directly with fisheries biologists and technicians and learned about fisheries ecology, science, and career opportunities. Many of these college interns received partial scholarships from funds provided through the sockeye salmon investigation project matched with contributions from Coastal

Villages Region Fund and Barrick Gold Corporation's Donlin Creek Project (now Donlin Creek LLC). We also worked closely with the Alaska Native Science and Engineering Program at the University of Alaska to enroll two of the college interns into that nationally recognized program.

KNA also employed eight Kuskokwim high school students as interns to assist with the associated field research. The high school interns worked directly with fisheries biologists and technicians and learned about fisheries ecology, science, and careers in the process. The high school internships were typically two to four weeks long and were an extension of the existing KNA high school internship program (Hildebrand and Orabutt 2006). These extensions provided the necessary link between the 1-week introductory internships and more advanced college internships and technician positions. Four out of the eight students returned in following years to work in more advanced internship or technician positions.

One of the main purposes of hiring and training rural Alaskan residents is to build the capacity of rural organizations and communities to participate in fisheries research and management. The theory is that by building the capacity of individuals they will in turn build the capacity of their organizations and communities. We have found that this works and in particular Hildebrand and Orabutt (2007) identified and discussed the positive impact on the capacity of Kuskokwim communities. However, the links between individual capacity and organizational and community capacity are not always clear and the transfer of capacity can be inhibited by lack of incentives to use new skills and knowledge, lack of community and peer support, cultural and economic factors, and lack of organizational support (IBRD 2008). Orabutt (2005) recognized that the local hiring and training of employees was slow to transfer into increased capacity of KNA due to low year-to-year employee retention and lack of employee promotion. Field seasons away from friends and family, missing subsistence activities, need for additional education and training to move into leadership positions, lack of year-round employment, and competing job opportunities were several of the many reasons for low employee retention and promotion.

To help transfer individual capacity to community capacity, we first sought to increase our employees' job satisfaction, job pride, and desire and ability to share their experiences. We focused on training employees on the importance of fisheries research and the integral role they play in implementing the field research and serving as a liaison between their communities and fisheries researchers. We also focused on employee community building by encouraging clear and continual communication, a spirit of cooperation among all partners' staff, and a common focus on achieving the goals and objectives of the research project. We asked our employees to share their experiences with others and documented their experiences with photos to aid in their informal communication with their family and community. We required many of our interns to create and deliver presentations to various public and professional audiences so that they shared their experiences in a formal manner. KNA took additional steps and developed a stronger training program, step-by-step position ranking system, stronger mentoring, and more focus on higher education (Orabutt and Thalhauser 2008). In response, employees have shown greater learning, more excitement, more positive attitudes, and more thorough understandings of the mission, goals, and objectives of fisheries research and management (authors' observation). These efforts have resulted in greater employee job satisfaction and an increase in employee retention and promotion. KNA and AVCP leadership have taken more ownership of these capacity building efforts which leads to stronger inner-organizational support and ultimately more effective capacity building. The response in Kuskokwim villages has been positive. At community and advisory group meetings, many local residents reported increased learning about and support for fisheries research and management in their communities resulting from local employment in the fisheries field. Though these employee systems are still in beginning stages, fragile, and in need of continual improvement, this intentional change in our approach to hiring and training local fisheries employees is an exemplary case of capacity building.

This example of successfully addressing the fisheries employee system at KNA, illustrates the complexities of organizational capacity building and the need to look beyond the obvious technical needs (e.g., fisheries biologist) of rural Alaskan Native organizations. Technical needs are very real and it is essential that rural Native organizations have qualified biologists managing their fisheries programs. However, all those involved in organizational capacity building must continually consider the organizational development factors of planning, human resources management, and business administrative principles, and how these factors play out in the relationships among the individuals, organizations, and communities.

CAPACITY BUILDING: KNA AND AVCP

The KNA and AVCP staff agreed to specific responsibilities and attempted to incorporate these responsibilities into each organization as a whole. When this worked, it represented true capacity building as a process. We were not always successful and often the responsibilities were completed by one of the already overworked biologists which did not represent capacity building so much as it did a temporary fix.

Staff from KNA, AVCP, and ADF&G worked closely together and communicated often to support each other's efforts in ensuring all objectives of the sockeye salmon studies were completed. Both AVCP and KNA assisted with proposal and study plan development, hired and managed interns and technicians, directly assisted with tagging salmon at the fish wheels and surveying juvenile salmon in the Holitna River, implemented an outreach program within their respective villages, and assisted in final report writing. In addition, KNA secured all land use permits, led the Aniak River tag recovery project, and assisted with maintaining remote radio receivers. This represented a new partnership between AVCP and ADF&G and an increase in involvement by AVCP in Kuskokwim fisheries research. This represented a continued partnership between KNA and ADF&G. The KNA's responsibilities were similar to but more involved than those of past salmon tagging projects (e.g., Stuby 2007; Pawluk et al. 2006).

The KNA and AVCP staff "learned by doing" as they conducted research and outreach for this project. Participating in the mentoring of college students and technicians furthered fisheries staff abilities to recruit and work with local residents. KNA and AVCP also learned from their local employees which helped further develop programs to better serve local needs. KNA and AVCP staff built greater networking skills, built stronger relationships with agency staff, and learned how to facilitate effective partnerships. KNA and AVCP staff also gained skills and insights into further developing their fisheries outreach program and adapting it to the interests of their communities. Through the outreach program, KNA and AVCP staff traveled to numerous communities and communicated directly, shared information, and built relationships which will be helpful to planning future research.

CAPACITY BUILDING: ADF&G

The capacity building goals of Alaska fisheries funding agencies and project leaders are usually focused on building the capacity of rural residents, rural organizations, and rural communities as were our initial goals of this effort. However, we realized that through fisheries studies such as the sockeye salmon investigations, the Kuskokwim Area ADF&G Commercial Fisheries Division continues to build their capacity as individuals and an organization to conduct outreach and work with local Native organizations, individuals, and communities. The ADF&G staff worked closely with KNA and AVCP staff to meet the objectives of this study and to support the professional development of Kuskokwim residents hired into intern and technician positions. In addition, ADF&G staff conducted outreach including working closely with the KRSMWG, writing news articles, visiting schools, interviewing with the local radio news station, and presenting results at regional and community meetings. The ADF&G staff "learned by doing" as they conducted this project and thus increased ADF&G capacity in community outreach and partnerships with Rural Alaskan Native organizations. In addition, as the ADF&G staff worked with local employees they received feedback and learned more about the Kuskokwim area from the perspective of local residents.

RECOMMENDATIONS

1. Future outreach and capacity building efforts need to be more evaluative and focused on "how well" rather than "what" we are doing. Investigators can add simple measures to their studies that will greatly aid in their individual efforts. Techniques such as interviewing meeting participants, surveying residents, and using advisory groups as focus groups to determine their opinions on outreach and capacity building efforts would be relatively easy to implement and would have the potential for substantially useful outcomes. The National Science Foundation (2008) recommends that 5–10% of a program budget be spent on evaluation (Frechtling-Westat 2002).
2. Future capacity building efforts need to focus more on capacity building as a process rather than capacity building as a quick technical fix. Our experience was consistent with the literature in that capacity building that focused on the process (i.e., how individuals, organizations, or societies behave) represents more stable and institutionalized change. Fisheries funding and mentoring agencies should be more concerned with how things are being completed rather than if things are being completed.
3. Ideally, technicians and interns should be continually employed on a part-time basis during the winter to assist with community outreach efforts such as teaching in the schools and hosting community meetings. This would aid in transferring capacity from the individual to the community and also increase the stature associated with working in fisheries.
4. Project leaders should invite prominent local leaders, elders, and local advisory members who are most supportive of capacity building efforts to speak to fisheries technicians and interns at preseason training to better aid in connecting the individuals to the community and to encourage the often younger interns and technicians.
5. Investigators need to continue to focus on employee retention and management including continuing to build a more supportive work environment and employee community.
6. Project leaders need to investigate the barriers to intern and technician recruitment into the fisheries career field. Part of this could be working with groups such as Alaska Native Science and Engineering Program that offer a more continuous and integrated junior high school through college support framework that includes academics as well as internships and social components.
7. Project leaders need to continue to encourage local control and initiative by frequent and clear communication with organization and community leaders. Biologists need to talk

with Native organization board of directors and executive directors as well with other community leaders.

8. Capacity building efforts of future studies need to strategically contribute to the long-term goals of capacity building. Proposals and study designs should specifically state how this will happen.
9. Proposals and study designs of future studies need to clearly identify capacity building in fisheries management agencies as a goal and tailor objectives to achieving this goal, rather than just tacking it on in some token manner.
10. Project leaders should forge new partnerships with local teachers and schools and create realistic local environment-based lesson using project data and study designs. These efforts would amplify research contributions and aid in developing future scientist and encourage future community participation.

ACKNOWLEDGEMENTS

This study was funded by the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative. Many individuals and organizations assisted with the outreach and capacity building associated with this study. The KNA, AVCP, and ADF&G staff did a tremendous job making outreach and capacity building efforts a priority and we must thank the many biologist, administration staff, interns, and technicians that made these efforts possible. We would like to thank many community members that assisted with community meetings including Pete Mellick, Evelyn Thomas, Mary Willis, Ursula Graham, Angie Morgan, Bonnie Aloysius, Billy Jean Stewart, Father Nick Isaac, and Marry Willis. We would also like to thank the teachers and school officials that assisted us in the school portions of our outreach as well as with setting up community meetings including John Fremin, Richard Spencer, Bruce Richardson, Susan Hubbard, Art Wooderson, Joanne Vanfleteren, Molly Sakar, Bethany Barney, Linda Casassa, Amoret Allen, Alice Tucker, Maurya Fox, Linda Thacker, Willis Ferenbaugh, Dave LeMaster, Marcus Dammeyer, Jackie Williams, Sue McDonnell, and Brad Allen.

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TABLES

Table 3.1.–Regional meetings that included presentations about the Kuskokwim River sockeye salmon investigation.

Meeting or Event	Location	Date	Estimated Number of People Attending
KNA Tribal Gathering	Aniak	January 16–18, 2006	45 people: 10 council members, 20 organization representatives, and 15 community members
Western Interior Regional Advisory Council Meeting	Koyukuk	March 7–9, 2006	Council members, area biologists, and community members
Kuskokwim River Salmon Management Working Group	Bethel (Teleconference)	Throughout summer 2006	Working Group members, area biologists, and community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Bethel	September 5–6, 2006	Council members, area biologists, and community members
Western Interior Regional Advisory Council Meeting	Ruby	September 12–13, 2006	Council members, area biologists, and community members
Kuskokwim Fisheries Interagency Meeting	Anchorage	November 7–8, 2006	Area biologists, funding organization representatives, regional agency staff, and advisory group members
Central Kuskokwim State Advisory Committee	Aniak	November 29, 2006	Committee members, area biologists, and community members
KNA Tribal Gathering	Aniak	January 25–26, 2007	48 people: 12 council members, 20 organization representatives, and 16 community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Hooper Bay	March 13–15, 2007	Council members, area biologists, and community members
Kuskokwim Fisheries Interagency Meeting	Anchorage	April 17–18, 2007	Area biologists, funding organization representatives, regional agency staff, and advisory group members
Western Interior Regional Advisory Council Meeting	Aniak	March 6–7, 2007	Committee members, area biologists, and community members
Kuskokwim River Salmon Management Working Group	Bethel	Throughout summer 2007	Working Group members, area biologists, and community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Marshall	September 5–6, 2007	Committee members, area biologists, and community members
Western Interior Regional Advisory Council Meeting	Galena	October 30–31, 2007	Committee members, area biologists, and community members
Kuskokwim Fisheries Interagency Meeting	Anchorage	November 28–29, 2007	Area biologists, funding organization representatives, regional agency staff, and advisory group members
Western Interior Regional Advisory Council Meeting	Fairbanks	February 28–29, 2008	Committee members, area biologists, and community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Lower Kalskag	March 20–21, 2008	Committee members, area biologists, and community members

Table 3.2.–Community outreach meetings associated with the Kuskokwim River sockeye salmon investigation.

Meeting or Event	Location	Date	Estimated Number of People Attending
Kwethluk IRA Council Meeting	Kwethluk	March 21, 2006	5 council members
Tuluksak Tribal Council Meeting	Tuluksak	April 17, 2006	6 council members
Goodnews Bay Tribal Council	Goodnews Bay	May 15, 2006	5 council staff
Stony River Community Meeting	Stony River	December 7-8, 2006	3 council members
Crooked Creek Community Meeting	Crooked Creek	December 12, 2006	11 people: 2 council members, 1 adult community member, and 8 high school students
Lime Village Community Meeting	Lime Village	January 16, 2007	6 people: 2 council members and 4 community members
KNA Intern Aniak Community Presentations	Aniak	August 15, 2007	5 adult community members
Lower Kalskag Community Meeting	Lower Kalskag	December 12, 2007	15 people: 3 council members and 12 community members
Red Devil Community Meeting	Red Devil	December 18, 2007	6 people: 2 adult community members and 4 children
Anaik Community Meeting	Aniak	April 17, 2008	4 people: 1 council member and 3 community members

Table 3.3.–School presentations about the Kuskokwim River sockeye salmon investigation.

School Visited	Location	Date	Estimated Number of People Attending
Kwethluk High School	Kwethluk	March 21, 2006	30 students, 4 teachers/admin staff, and 5 community members
Tuluksak High School	Tuluksak	April 17, 2006	15 high school students
Chuathbaluk School	Chuathbaluk	April 24, 2006	25 students and 3 teachers
Aniak High School	Aniak	April 25, 2006	12 students and 1 teacher
Kalskag High School	Kalskag	May 2, 2006	30 students and 1 teacher
Goodnews Bay High School	Goodnews Bay	May 16, 2006	12 students and 1 science teacher
Aniak High School	Aniak	December 4–5, 2006	12 students and 1 teacher
Stony River Schools	Stony River	December 7–8, 2006	15 people: 6 K–4 grade, 6 6–12 grade, 2 teachers, and 1 teachers aid
Crooked Creek Schools	Crooked Creek	December 11–12, 2006	44 people: 16 K–3 grade, 12 4–6 grade, 12 7–12 grade, 3 teachers, and 1 teacher aid
Lime Village Schools	Lime Village	January 16, 2007	9 students 7–12, 1 teacher, and 1 teacher aid
Napaskiak High School	Napaskiak	January 22, 2007	30 students and 2 teachers
Oscarville School	Oscarville	January 29, 2007	10 students and 2 teachers
Napakiak School	Napakiak	January 30, 2007	12 students and 1 teacher
Akiak High School	Akiak	March 20, 2007	30 students and 1 teacher

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Table 3.3.–Page 2 of 2.

School Visited	Location	Date	Estimated Number of People Attending
Tuluksak High School	Tuluksak	April 10, 2007	13 high school students
Bethel Regional High School	Bethel	April 12, 2007	16 ecology/biology students
Mt. Edgecumb	Sitka	April 15–16, 2007	20 students: many top YK Delta students attend this school
Quinhagak High School	Quinhagak	May 8–9, 2007	17 students, 1 science teacher, and 1 principle
Kwethluk High School	Kwethluk	May 10, 2007	30 students
Nunapitchuk High School	Nunapitchuk	May 17, 2007	10 students
Tuntutuliak Schools	Tuntutuliak	May 18, 2007	9 students and 2 teachers
Aniak Elementary School	Aniak	November 7, 2007	25 students and 1 teacher
Kalskag Schools	Kalskag and Lower Kalskag	December 10–13, 2007	125 students and 5 teachers
Red Devil Schools	Red Devil	December 17–19, 2007	15 students and 2 teachers
Chuathbaluk School	Chuathbaluk	December 20, 2007	30 students and 4 teachers
Aniak High School	Aniak	March 25–26, 2008	30 students and 1 teacher
Sleetmute Schools	Sleetmute	April 14–15, 2008	6 students and 2 teachers
Crooked Creek Schools	Crooked Creek	April 15–16, 2008	30 students, 4 teachers, and 1 teachers aid

APPENDIX 3.A: ADF&G MEMO REGARDING OPERATION OF LOWER KUSKOKWIM RIVER TEST FISHERY

State of Alaska Memorandum

Department of Fish and Game

Commercial Fisheries Management and Development Division

TO:	Tom Kron AYK Regional Supervisor Anchorage	**DATE:**	3 June, 1996
		FILE:	LKTF96ME.DOC
		PHONE:	543-2648
FROM:	Doug Molyneaux Kuskokwim Research Biologist AYK - Bethel	**SUBJECT:**	Operation of the Lower Kuskokwim Test Fishery in 1996

It just recently came to my attention that the Association of Village Council Presidents (AVCP) and the Bering Sea Fishermen's Association (BSFA) intend to operate the Lower Kuskokwim Test Fishery (LKTF) in 1996, in spite of repeated recommendations to the contrary. The purpose of this memo is to describe my reasons for not supporting the continued operation of the LKTF, discuss some concerns in how it will be operated, and offer some possible alternatives which would be more promising investments for the available funds.

The objectives of the LKTF, as described by AVCP, are to determine the relative timing and run abundance of salmon species as they enter the lower Kuskokwim River. A test fishery can only provide reliable run timing information if the project is optimally located and optimally performed. Test fisheries can also approximate *within season* changes in salmon abundance, but the information only applies to the point where the test fishery is being operated. Again, the usefulness and reliability of this information is dependent on the project being optimally placed and optimally executed. Estimating *between season* differences in abundance is a weak point for even the most optimally located and executed test-fish projects. This was discussed at length during our preseason staff meeting and during preparation for the April 1996 Board of Fisheries meeting. The LKTF is not optimally placed and it cannot be optimally executed, therefore the project objectives cannot be achieved

The LKTF is located near the mouth of the Kuskokwim River and this results in a number of overwhelming challenges. Most notably, this portion of the river is a milling area for adult salmon. Returning salmon periodically hold in the area, for a variable period of time, to allow their bodies to adapt to the transition into freshwater and to await environmental cues which prompt upstream migration. On occasions when milling is prolonged test-fish catches can be exceptionally high and can lead observers to the false conclusion that the salmon run is strong. During these instances the good catches are a result of the build-up of milling fish. The good catches do not necessarily mean the run is strong. This milling phenomenon has misled managers in the past and confounds efforts to use lower river test fisheries as a measure of run timing and relative run abundance.

The expansive size and channel dynamics of the lower Kuskokwim River also thwart efforts to develop a reliable test fishery in the area. At the point where the LKTF is operated, the river is approximately four miles across with two prominent channels, each channel being a mile in width. The profile of each of these channels is exceptionally dynamic. Even the barge traffic must switch between channels every few years. Certainly the fish behavior is affected by these changing current patterns and this would profoundly impact the between season comparability of any test fish data.

A secondary effect of the expansive size of the lower Kuskokwim River is that modestly high winds, 20 to 25 knots, create very rough boating conditions. The wind and waves make it difficult to keep the nets fishing well. During high wind events the fishers are commonly forced to stay on the beach. This is especially bad for a test fish index because, as observed in other test fisheries, the best catches often occur during high wind events. Again, these conditions significantly erode the reliability of any lower river test fishery as an index of run timing and relative abundance.

Disposal of the catch has been another problem of test fisheries operated in the lower Kuskokwim River. Commercial outlets are not readily available, so early in the season the test-fish catches are distributed to subsistence users. But that option quickly dissipates in the second half of June when catches increase and chum salmon dominate. Commercial processors can be coaxed to take the fish when they have tenders passing through the area, but tenders are not always available and dedicated tendering just for the test fishery is a costly venture. As a result, the test-fishers typically undertake measures to intentionally reduce their catches. Among the methods are shortening the drift times, using shorter nets, or reducing the number of drifts conducted each tide. The alternative is to not fish at all and that alternative has occasionally been invoked. Again, these operational shortfalls erode the reliability of the LKTF as an index of run timing and relative abundance.

Test fisheries have been tried in the lower Kuskokwim River for decades and all have failed for basically the same reason - the lower Kuskokwim River is a poor location for a test fishery. In their justification for operating the LKTF, AVCP states that careful management is needed to provide proper salmon management. Given the shortfalls described above, it seems clear that the LKTF does not qualify as a “careful” management tool. As such, it will not contribute to “proper” salmon management; in fact, the opposite is likely to be true. The Department should not invest any further resources into this black hole when other, more promising work is so desperately needed in the area. The welfare of the salmon and public would be better served if efforts were focused on more rigorously operated run assessment and spawning ground assessment projects.

I would hope that staff from the BSFA would reconsider their plans to fund the operation of the LKTF. Those funds could be put to much better use if invested in other run assessment and spawning ground assessment projects. For example, the operating time for the George River weir, Kwethluk River counting tower, and Kanektok River counting tower could be extended to include coho salmon. Coho salmon are poorly studied in the Kuskokwim Area. Extremely little is known about their spawning escapement levels. Meanwhile, that species is rapidly becoming the most valuable salmon resource in the Area. Managers are pressured to allow greater and greater commercial harvest of coho salmon as other economic opportunities dwindle. The impact of the increased harvest levels is unknown.

At the very least, the BSFA funds could be redirected to extend operation of the existing cooperative escapement projects so they provide more complete coverage of the chum salmon run. This is especially important during the first few years during which these projects are operated because the actual run timings are poorly studied or unknown and reliable estimates cannot be made for that portion of the run not counted. Currently, funding levels for all three projects require that counting operations be discontinued by about July 31. It is unknown whether this will be sufficient time to span the entire chum salmon escapement past the George River weir. For the Kwethluk River, during the one year when U.S. Fish and Wildlife operated a weir on the river, 84% of the chum salmon passage had occurred by July 31. In a neighboring stream, the Tuluksak River, a weir was operated for four years and the chum salmon passage by July 31 ranged from 72% to 90%. The most comparable stream for estimating chum salmon run timing for the Kanektok River is the Goodnews River. Chum salmon passage at the Middle Fork Goodnews River weir averages 97% through July 31 (sockeye average 99%). Clearly, the need to extend operational time is mostly at the George River weir and the Kwethluk River counting tower.

Another potential application for the BSFA funds is to extend the genetic stock identification baseline of chum salmon in the Kuskokwim Area. There are numerous gaps in the genetics baseline, especially in the upper Kuskokwim drainage and in the late spawning chum salmon populations.

Staff time in the Kuskokwim is already fully allocated. I don't believe any staff member can afford to help BSFA and AVCP operate the LKTF as we have in the past. Given the shortfalls described above it would not be prudent to reallocate any staff time to the LKTF since it will not prove to be a rigorous and useful management tool. If AVCP is allowed to operate the LKTF without support from the Department, then some issues need to be addressed:

1. Can the test fishery be operated when the subsistence fishery is closed?
2. Can AVCP sell fish caught in the test fishery?
3. How are ADF&G staff to deal with the public and Working Group if data from the LKTF conflicts with other more rigorously operated run assessment projects?
4. If we support the test fishery, in any way, does this not imply that we feel the project has merit? And how is this viewed by observers from outside the Kuskokwim Area? Are we going to use this type of information in Emergency Orders to justify announcements of commercial fishing periods? Will this information appear in the AMR and the BOF reports? Will our continued support for the project contribute to the erosion of the Departments credibility in managing salmon in the Kuskokwim Area?

cc:

Buklis
Cannon
Bromaghin
Burkey
Anderson

APPENDIX 3.B: DELTA DISCOVERY ARTICLE KUSKOKWIM RIVER SOCKEYE SALMON: SECRETS REVEALED

Kuskokwim River Sockeye Salmon: Secrets Revealed

By Doug Molyneaux and Sara Gilk

Sockeye salmon in the Kuskokwim River have largely been a mystery to the biologist charged with managing salmon harvest. Considered an “incidental species,” the sockeye entering the Kuskokwim River every June and July were mostly thought to be traveling to Telaquana Lake in the Stony River drainage, which is about the only place in the Kuskokwim basin with the type of lake characteristic of “text book” sockeye salmon habitat.

“Text book” sockeye typically lay their eggs in or near lakes. After the eggs hatch, the offspring live in the lake for one to three years, then migrate to the ocean where the young fish live another two or three years before returning to their birth place to spawn and die. But Kuskokwim River sockeye are teaching us that they are not a “text book” variety.

An investigation by the Alaska Department of Fish and Game, in partnership with Kuskokwim Native Association, National Park Service, Natural Resource Consultants, Inc., and Association of Village Council Presidents, seeks to learn where Kuskokwim River sockeye are spawning, and where the juvenile sockeye are rearing before they go out to sea.

In 2005 Coastal Villages Region Fund provided seed money for a pilot project whose results prompted a full scale investigation scheduled for 2006 and 2007. Funding for the investigation is from Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative, with matching funds from Coastal Villages Region Fund, the Federal Office of Subsistence Management, National Park Service, and the State of Alaska.

In this investigation biologists are using radiotelemetry to uncover some of the sockeye’s secrets. About 500 sockeye were caught this year in specially modified fish wheels operated near Kalskag, and the fish were helped to swallow a small radio transmitter. The transmitter is a slippery two inch long cylinder that sits in the stomach of the fish. Salmon don’t eat while they are migrating up the river, so the transmitter does not interfere with the fish.

Each transmitter has a unique number, which is like giving each fish a unique name. The transmitter sends out a signal broadcasting that number similar to how a radio station like KYUK or KSKO sends out a signal broadcasting music. But you cannot hear the music of KYUK or KSKO unless you have a radio to receive the signal. In this same way, the number identifying the transmitter in a sockeye salmon is broadcast continually, but you can only hear the number if you have a “receiver”.

Not all sockeye caught in the fish wheels get a radio transmitter. Fish are carefully selected in a way that mirrors sockeye salmon abundance as the run builds, peaks, and then tapers off. The selection also mirrors differences in sockeye abundance between the north and south banks.

Biologists use radiotelemetry to track the location of each fish. Every few weeks a biologist gets into a small airplane to survey the Kuskokwim River basin. Holding a receiver in his or her lap, the biologist listens for the transmitter signals of sockeye salmon. Unlike a radio station, the signal broadcasted by the transmitter in sockeye can only be heard over a short distance. When the biologist hears a signal they know they are close to the salmon, and they mark the location on a map. The result is a map that shows were these fish are traveling and spawning.

The investigation is not yet complete, but to everyone's astonishment, only 17 percent of the sockeye have gone to Stony River and Telaquana Lake. The majority of sockeye, 70 percent, are instead going up the Holitna River, and they are not spawning near any lake like "text book" sockeye.

In another part of the study, we are finding that after they hatch the young Holitna sockeye are rearing in spring-fed side-sloughs in the Holitna basin. This is also very different from the "text book" version of sockeye life history, but the Holitna sockeye are doing very well.

One of the important aspects of this finding is that it highlights the importance of the Holitna River basin for salmon production. In addition to sockeye, the Holitna River basin produces perhaps as much as a half of all Kuskokwim River king salmon, plus it is a major producer of chum and coho salmon. The Holitna River basin feeds subsistence fishers throughout most of the Kuskokwim River, and supports the modest commercial fishery of the lower Kuskokwim River.

In recognition of its importance, some village councils are moving to have the Holitna basin established as a Fish and Game reserve. The proposed reserve would be open to hunting, trapping, and fishing, but other development would be limited so as not to harm the fish and wildlife. The groups currently spearheading this initiative are Orutsaramuit Native Council of Bethel and Sleetmute Traditional Council. The Alaska Board of Game has already recognized and endorsed this proposal, and it will go before the Alaska Board of Fisheries for endorsement when the Board of Fisheries meets January 31 to February 5 in Anchorage. Actual establishment of the reserve will take an act of the State Legislature.

Doug Molyneaux and Sara Gilk are Kuskokwim Area salmon research biologists for the Alaska Department of Fish and Game.