Final Report Summary

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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 by the Alaska Board of Fisheries to allow directed commercial harvest on sockeye under a guideline harvest level; however, fundamental knowledge about basic biology and ecology of sockeye salmon in the Kuskokwim River has been lacking. Our aim was to begin addressing these data gaps by describing the 1) spawning distribution, 2) stock-specific run and migration timing, 3) relative abundance, 4) habitat use and seasonal migration patterns of river-type and lake-type juveniles, and 5) smolt size and growth among tributaries and habitat types. Results indicate that river-type sockeye salmon are far more important to the overall Kuskokwim River sockeye run than previously believed, particularly those spawning in the Holitna River basin which accounted for about 70 percent of the final destination of tagged fish. Other major contributors included the Stony River (lake-type), and Aniak River (river-type). River-type sockeye tend to have more volatile productivity than lake-type populations, so given the dominance of river-type fish in the Kuskokwim River, fisheries managers should anticipate highly variable annual returns that may be difficult to predict. 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. Results 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. Future measures should include establishing an escapement monitoring program representative of the stock diversity found within Kuskokwim River sockeye salmon, including escapement goals.

Approach: Adult Distribution, Run Timing, and Migration Rates

Adult sockeye salmon were captured in 2006 and 2007 on the mainstem Kuskokwim River and fitted with radio and/or anchor tags. Captures were made at approximately rkm 270 using two fish wheels operated from early June to mid August, and fished 7 days per week in 2006 and 6 days per week in 2007, for about 9 hours each day during daylight hours. One fish wheel was located along the north bank and the other along the south bank, and each was equipped with a live box for holding fish prior to tagging. Throughout each day, the 2 to 3 person crew rotated between the 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 were immediately release. 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). 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 $\leq$ 400 mm mideye-fork length (MEF length) results in a higher probability of stomach rupture; therefore, fish smaller 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; ADFG, Anchorage, unpublished data).

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 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), so efforts were made to limit holding time (time of capture though time of release) to less than one hour for all radio-tagged sockeye salmon. Fish that were obviously injured, appear stressed, or were held more than 1 hour were not radio-tagged.

In addition to an internal radio transmitter, all radio-tagged 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 radio tagged 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, mid-eye-fork (MEF) length, condition of fish, and hold time. Immediately after tagging, fish were released.

In order to examine possible tag deployment biases, all other sockeye salmon were tagged with a uniquely-numbered 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 bank of capture, plus the adipose fin was removed as a secondary mark to allow for assessing tag loss. The primary focus of this study relates to findings from the radio-tag deployments.

Radio-tagged 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 at the lower end of major sub-basins and at escapement weirs. 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 surveys included coverage of the mainstem Kuskokwim River, major tributaries, and many smaller tributaries. Purposes of aerial surveys were to: 1) locate radio-tagged fish that had not yet migrated into a spawning stream (including fates such as tag loss, handling mortality, or harvest), 2) locate tagged fish in spawning tributaries other than those monitored with tracking stations, 3) locate fish that ground-based stations failed to record, and 4) validate records from the ground-based stations. Two drainage-wide aerial 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 these surveys bracketed the period when most sockeye salmon were likely to be on spawning grounds. 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 1-2 seconds. Once a tag was located its frequency, code, and latitude/longitude were recorded by the receiver.

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

Findings from radio tag deployment were used to describe the spawning distribution of sockeye salmon upstream of Kalskag, to describe stock-specific run

timings past the tagging site, and to describe stock-specific migration rates. "Stock" as used here can refer to spawning aggregates inclusive of a large 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 both radio- and anchor tag information.

Distribution was described by mapping the final destination of radio-tagged fish as determined from both ground-based receiver stations and aerial surveys. "Final destination" was defined as the farthest upstream location reported for a radio-tagged fish within any tributary of the Kuskokwim River. Radio-tags not found in a tributary stream were excluded. Fish that were detected downstream of the tagging site and that did not resume upstream migration (here, defined as passing the first upstream tracking site at Birch Tree Crossing, rkm 294) were also excluded. The proportion of radio-tagged sockeye salmon that returned to a particular tributary was calculated with adjustments to account for changes in the daily radio-tagging rate and fishing effort (Wuttig and Evenson 2002). Bootstrap techniques were used to estimate variance and confidence intervals.

Stock-specific run timings at the tagging site were described through examination of the tagging date for each radio-tagged salmon that successfully reach a spawning area (Mundy 1979, Merritt and Roberson 1986, Keefer et al. 2004). The mean and variance of the date of passage for each stock were calculated using methods described by Mundy (1979). 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 radio-tagged 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. Additionally, migration rates of radio-tagged fish returning to the Holitna and Stony rivers were compared over a stretch of 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).

Juvenile Habitat and Growth
Juvenile salmon were sampled by river seine in the Kogrukluk River, which is a major tributary of the upper Holitna River approximately 710 river kilometers (rkm) from the ocean, and in the lower Holitna River, approximately 491 rkm from the ocean. 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 (Shelden et al. 2005, Gilk et al. 2009), whereas little, if any, spawning occurs in the lower Holitna River (few gravel areas). Sampling occurred from late June 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. 2006). 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. 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 large water containers. 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, which was a wide (~150 m) low gradient river. 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.

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 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. The digital image was loaded in Optimas 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 1) some adult scales were resorbed along the outer edge, and 2) allometry of scales and salmon length changes from juvenile to adult life stages (Fisher and Pearcy 2005). Therefore, as recommended by Fisher and Pearcy (2006), 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.

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 a fish wheel at Kalskag (rkm 270), then live-released after tagging with an esophageal radio transmitter (Gilk et al. 2009). Spawning area of tagged salmon was determined by aerial surveys and by remote receivers located in select drainages. 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 station on the Aniak River. 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 weirs and sonar stations 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. 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, such as 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 & 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 underestimate variability in size.

Adult sockeye salmon were randomly sampled from the Kalskag fish wheel catch (Gilk et al. 2009); 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 sampled from seven other watersheds in Alaska (Kvichak, Egegik, Nushagak District, Black Lake, Kasilof, Kenai, Coghill) during the past 30-40 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 (FWPL) of sockeye salmon from these other watersheds was the same as that used for Kuskokwim sockeye salmon.

Radiotelemetry was conducted in cooperation with the Kuskokwim Native Association, Association of Village Council Presidents, National Park Service, and ADF&G. Juvenile and scale sample collection was conducted in cooperation with National Park Service, U.S. Fish and Wildlife Service, Kuskokwim Native Association, Takotna Tribal Council, Organized Village of Kwethluk, Association of Village Council Presidents, University of Montana/Salmonid Rivers Observatory Network, and ADF&G. Outreach efforts were conducted in cooperation with Kuskokwim Native Association, Association of Village Council Presidents, and ADF&G.

References cited, and tables and figures are available in the draft final ADF&G FDS product (attached).

Results/Findings:
Adult Distribution, Run Timing, and Migration Rates
The temporal distribution of deployed radio tags was a few days earlier than the overall run timing as estimated by catches in the fish wheel in both 2006 and 2007 (Figure 1.2). In 2006, 498 radio tags were deployed, the first on 14 June and the last on 15 August. In 2007, 488 radio tags were deployed, the first on 21 June and the last on 14 August. In 2006, 50% of radio tags were deployed in fish captured on the north bank and 50% were deployed on the north bank. In 2007, 48% of radio tags were deployed in fish captured on the north bank, 50% were deployed on the south bank, and 2% of deployed tags had incomplete information records. There was no difference between bank of origin in the ratio of tags reported at most tributaries, with the exception of Aniak River. In 2006, 70% of Aniak River fish were tagged on the south bank; in 2007, 60% of Aniak River fish were tagged on the south bank.

Fates were described for all radio-tagged fish (Table 1.1). In both 2006 and 2007, 3% of radio-tagged fish either lost their tags or were never located after tagging. In 2006, 9% of radio-tagged 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 radio-tagged fish was similar in 2006 and 2007 (Table 1.2; Figure 1.3). The most common age group in both years was age-1.3 (79% in 2006 and 72% in 2006), followed by age-1.2 (9% in 2006 and 16% in 2007). No 0-check fish were among those radio-tagged in 2006, but four were found among the 2007 deployments. (Zero-check fish undergo smoltification within a few months after emergence from the gravel, so their scales have no freshwater annulus or "check".) Females accounted for 41% and 40% of radio-tagged fish in the two years. Lengths of radio-tagged fish were generally similar in 2006 and 2007 (Figure 1.3).

Radio-tagged sockeye salmon primarily traveled to tributaries within the middle Kuskokwim River basin (Figures 1.4, 1.5). Based on the weighted distributions, Holitna River sub-basin accounted for 71% of the fish in 2006 and 70% in 2007, followed by the Stony River sub-basin with 15% in 2006 and 19% in 2007, and then the Aniak River sub-basin with 9% in 2006 and 8% in 2007 (Tables 1.3, 1.4). Smaller numbers of fish were tracked to the Holokuk (1 - 3% in each year), Oskawalik (< 1% - 1% in each year), and George (< 1% - 1% in each year) rivers. In 2006, one radio-tagged fish returned to Vreeland Creek and one to the Swift River drainage. No radio-tagged sockeye were found in the Kuskokwim River basin upstream of the Swift River drainage in either year.

Within the Holitna River sub-basin, radio-tagged 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, which accounted for 34% of the weighted Kuskokwim River distribution in 2006, and 25% in 2007. Also important were the Hoholitna (15% of fish in 2006 and 21% in 2007), the Kogrukluk (15% in 2006 and 17% in 2007), and the Chukowan rivers (7% in 2006 and 6% in 2007). No radio-tagged fish entered Whitefish Lake.

Within the Stony River sub-basin, radio-tagged fish were tracked to locations in either mainstem Stony River or one of two lake systems (Tables 1.3, 1.4). Mainstem areas accounted for 5% of the weighted Kuskokwim River distribution in both 2006 and 2007. The Telaquana River/Lake drainage accounted for 6% in both years; and the Necons River/Two Lakes drainage accounted for 3% and 8%.

Within the Aniak River sub-basin, radio-tagged fish were found in both the mainstem Aniak River and various tributaries (Tables 1.3, 1.4). The majority were tracked to the mainstem Aniak River downstream of the confluence with the Salmon and Kipchuk rivers, which accounted for 6% of the weighted Kuskokwim River distribution in 2006, and 4% in 2007. The upper mainstem Aniak River upstream of the Salmon and Kipchuk rivers accounted for 3% of the fish in both years. Also important was the Kipchuk River drainage with 1% of the fish in both years. No radio-tagged sockeye salmon were tracked to Aniak Lake.

Migratory timing patterns of stocks past the Kalskag tagging site were similar in 2006 and 2007 (Figure 1.6). The median date of passage for Stony River radio-

tagged fish was 3 July in 2006 and 2 July in 2007. The median date of passage for fish traveling to the Holitna River sub-basin was 5 July in 2006 and 7 July in 2007, and for Aniak River fish 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 the Stony and Aniak fish ($D = 0.339$, $P < 0.01$) and between Holitna and Aniak fish ($D = 0.250$, $P < 0.05$), but not between the Stony and Holitna fish ($D = 0.178$, $P = 0.075$). In 2007 there was a significant difference in run timing between Stony and Aniak fish ($D = 0.539$, $P < 0.001$) and between Stony and Holitna fish ($D = 0.372$, $P < 0.001$), but not between the Holitna and Aniak fish ($D = 0.167$, $P = 0.478$).

In both years, Aniak River fish traveled an average of 12.5 rkm/day in 2006 and 9.5 rkm/day in 2007 to travel from the Birch Tree Crossing start point to the ground-based receiver in the lower Aniak River (Table 1.5). Stony River fish traveled an average of 29.7 rkm/day in 2006 and 28.6 rkm/day in 2007 to migrate from Birch Tree Crossing to the receiver in the lower Stony River. Holitna River fish traveled fastest, passing the lower Holitna River receiver at an average rate of 37.0 rkm/day in 2006 and 31.3 rkm/day in 2007. Among Holitna River fish, fish tracked to the Hoholitna River traveled at 37.2 rkm/day and 31.8 rkm/day in 2006 and 2007, while those tracked to the Kogrukluk River traveled at 24.3 rkm/day in 2006 and 22.0 rkm/day in 2007. Among the Stony River fish, those tracked to Telaquana Lake traveled at a slower rate of 22.5 rkm/day and 22.4 rkm/day in 2006 and 2007.

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, Holitna River fish traveled at a 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 ($P < 0.05$), but not 2007.

Juvenile Habitat and Growth
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 three salmon per set during late August through late September (Figure 2.3). No yearling sockeye salmon were captured indicating most yearling 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 (Figure 2.4; Table 2.1) (g.m. = 4 fish; two factor ANOVA: df = 2, 62; F = 11.415, $P < 0.001$). 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 Chinook salmon per set in late June to 13.7 Chinook salmon 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 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 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 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, juvenile grayling and pike) peaked in late July (Figure 2.3), and there was no difference in CPUE between habitats (Table 2.1). No rainbow trout and only four char were captured in the Kogrukluk 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 fry were captured, sockeye 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 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, grayling, 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 were observed in mid-channel, but none were captured in the seine.

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 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 were captured in the Holitna River for calculation of mean size.

Juvenile sockeye 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 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 (see below) using the two models, sockeye 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 scales were examined from adult salmon returning to 16 drainages and areas within the Kuskokwim watershed. These areas ranged from the Kwethluk River in the lower watershed (~190 rkm from ocean) to Telaquana Lake in the upper watershed (~790 rkm from ocean). Juvenile sockeye salmon lengths were estimated 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. The following text 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 (Two Lakes in Stony River watershed) to 108 ± 1.4 mm in Telaquana Lake (upper Stony River) when samples from all years were combined (Figure 2.10). Mean length of sockeye salmon at the end of the spring smolt period (FW1 & FWPL) ranged from 96 ± 2.3 mm (Salmon River in upper Aniak River) to 117 ± 1.3 mm in Telaquana Lake (Figure 2.10). Estimated 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 spawning along the mainstem Kuskokwim River primarily upstream of Kalskag. 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 below).

Growth of juvenile sockeye salmon was compared between Kuskokwim watersheds 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, 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 of Telaquana Lake sockeye salmon during the smolt migration period was less than other stocks in 2007 but typical of other stocks in 2006.

Back-calculated lengths of river-rearing sockeye salmon were compared with estimated lengths of lake-rearing sockeye salmon. Nearly all lake-rearing sockeye salmon were from Telaquana Lake. Length of sockeye salmon at the end of the first growing season 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, at the end of the spring transition period, river-rearing sockeye salmon (105 mm) were 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).

Juvenile lengths estimated from adult salmon scales collected from the Kalskag fishwheel represent a random sample of sockeye salmon primarily rearing in the middle upper watershed and upstream, 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 & 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 during May-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 2004 (51.5°F) and relatively low during 2003 (48.6°F).

Kuskokwim scale growth (based on Kalskag samples) during the first year 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 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 that spawned in rivers without access to lake habitat (94% of total), indicating that scale growth of river-type sockeye in the Kuskokwim watershed (FW1: 0.41 mm; FW1 & 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 & FWPL: 0.25-0.55 mm).

References cited, and tables and figures are available in the draft final ADF&G FDS product (attached).

Evaluation: Project objectives were met. Specific objectives were to: 1) describe the location and relative abundance of sockeye salmon spawning aggregates (stocks) in tributaries of the Kuskokwim River upstream of Kalskag which constitute 5% or more of radio tags deployed in 2006 and 2007; 2) estimate run-timing in the mainstem Kuskokwim River for the stocks identified in Objective 1; 3) describe and compare habitat utilization and seasonal migration patterns of river-type and lake-type juvenile sockeye salmon in the Kuskokwim River in 2006; 4) describe and compare sockeye salmon smolt size and growth among different tributaries and habitat types of the Kuskokwim River drainage in 2005 through 2007; and 5) describe the relative importance of river-type versus lake-type sockeye salmon to total production of sockeye salmon in the Kuskokwim River based on the relative abundance of spawning adults.

Objectives 1 & 2 were met by conducting a radiotelemetry study in 2006 and 2007. Objectives 3 & 4 were met by conducting juvenile sampling in the Holitna River drainage, and by back-calculating freshwater growth from adult salmon scales collected from the radiotelemetry study. Objective 5 was met by compiling information collected from addressing objectives 1-4. No modifications were made to project objectives.

Project Products: Results from this project have been presented through the following:
- Presentations to peers and user groups at the Kuskokwim Area Fall and Spring Interagency Meetings, Anchorage, Alaska, 2006-2008..
- Newspaper article in "The Delta Discovery", September 6, 2006.
- Presentations and updates to the Kuskokwim River Salmon Management Working Group throughout 2006 and 2007.
- Presentations at meetings including Yukon-Kuskokwim Delta RAC, Western Interior RAC, Middle Kuskokwim Advisory Committee, KNA Tribal Gathering, other regional meetings in winters 2006-2007 and 2007-2008.
- Community meetings and school visits in 2006-2008 at various Kuskokwim River villages including: Chuathbaluk, Kalskag, Sleetmute, Stony River, Lime Village, Aniak, Crooked Creek, Red Devil.
- Presentations by AVCP and KNA college interns at an Intern Day sponsored by the U.S. Fish and Wildlife Service, Partners for Fisheries Monitoring Program in August 2006 and 2007.
- Presentation to scientific peers at Alaska Chapter of the American Fisheries Society meeting, Ketchikan, Alaska, November 2007.

Authors are submitting a draft copy of a detailed project report outlining the results of the study, prepared for the ADF&G Fishery Data Series. Additionally, one or two manuscripts are expected to be prepared for submission to peer-reviewed journals.

Key Words: sockeye salmon, *Oncorhynchus nerka*, radiotelemetry, juvenile, habitat, run timing, Holitna River, Telaquana Lake, Kuskokwim River, age-sex-length, river-type sockeye salmon, scale growth capacity building; outreach, education; public involvement; cooperative research

Date Prepared: May 15, 2009

Revised 10/31/03

2006 Arctic Yukon Kuskokwim Sustainable Salmon Initiative Project Final Product[1]

Kuskokwim Sockeye Salmon Investigations

by:

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May 29, 2009

AYK SSI Final Product, Kuskokwim Sockeye Salmon Investigations

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 by the Alaska Board of Fisheries to allow directed commercial harvest on sockeye under a guideline harvest level; however, fundamental knowledge about basic biology and ecology of sockeye salmon in the Kuskokwim River has been lacking. Our aim was to begin addressing these data gaps by describing the 1) spawning distribution, 2) stock-specific run and migration timing, 3) relative abundance, 4) habitat use and seasonal migration patterns of river-type and lake-type juveniles, and 5) smolt size and growth among tributaries and habitat types. Results indicate that river-type sockeye salmon are far more important to the overall Kuskokwim River sockeye run than previously believed, particularly those spawning in the Holitna River basin which accounted for about 70 percent of the final destination of tagged fish. Other major contributors included the Stony River (lake-type), and Aniak River (river-type). River-type sockeye tend to have more volatile productivity than lake-type populations, so given the dominance of river-type fish in the Kuskokwim River, fisheries managers should anticipate highly variable annual returns that may be difficult to predict. 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. Results 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. Future measures should include establishing an escapement monitoring program representative of the stock diversity found within Kuskokwim River sockeye salmon, including escapement goals.

PRESS RELEASE:

Sockeye salmon in the Kuskokwim River have largely been a mystery to salmon managers. 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 one of few places in the Kuskokwim basin with lake habitat characteristic of typical sockeye. Typically, sockeye 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 spawn (lake-type sockeye). However, Kuskokwim sockeye appear to have more diverse life history strategies, including rearing in river environments before migrating to sea (river-type sockeye) 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, sought to learn where Kuskokwim River sockeye are spawning, and where the juvenile sockeye are rearing before they go out to sea.

Radiotelemetry studies indicated that river-type sockeye salmon are far more important to the overall Kuskokwim River sockeye run than previously believed, particularly those spawning in the Holitna River basin which accounted for about 70 percent of the final destination of tagged fish. Other major contributors included the Stony River (lake-type), and Aniak River (river-type). Juvenile studies 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. River-type sockeye tend to have more volatile productivity than lake-type populations, so given the dominance of river-type fish in the Kuskokwim River, fisheries managers should anticipate highly variable annual returns that may be difficult to predict. 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.

During this study we developed and implemented a specific outreach and capacity building plan that was nested within several other more long-term programs. All these efforts were mutually supportive of one-another and were part of a multi-level, strategic approach to outreach and capacity building in the Kuskokwim area.

PROJECT EVALUATION:

Project objectives were met. Specific objectives were to: 1) describe the location and relative abundance of sockeye salmon spawning aggregates (stocks) in tributaries of the Kuskokwim River upstream of Kalskag which constitute 5% or more of radio tags deployed in 2006 and 2007; 2) estimate run-timing in the mainstem Kuskokwim River for the stocks identified in Objective 1; 3) describe and compare habitat utilization and seasonal migration patterns of river-type and lake-type juvenile sockeye salmon in the Kuskokwim River in 2006; 4) describe and compare sockeye salmon smolt size and growth among different tributaries and habitat types of the Kuskokwim River drainage in 2005 through 2007; and 5) describe the relative importance of river-type versus lake-type sockeye salmon to total production of sockeye salmon in the Kuskokwim River based on the relative abundance of spawning adults. Objectives 1 & 2 were met by conducting a radiotelemetry study in 2006 and 2007. Objectives 3 & 4 were met by conducting juvenile sampling in the Holitna River drainage, and by back-calculating freshwater growth from adult salmon scales collected from the radiotelemetry study. Objective 5 was met by compiling information collected from addressing objectives 1-4. No modifications were made to project objectives.

DELIVERABLES:

Results from this project have been presented through the following:
- Presentations to peers and user groups at the Kuskokwim Area Fall and Spring Interagency Meetings, Anchorage, Alaska, 2006-2008.
- Newspaper article in "The Delta Discovery", September 6, 2006.
- Presentations and updates to the Kuskokwim River Salmon Management Working Group throughout 2006 and 2007.
- Presentations at meetings including Yukon-Kuskokwim Delta RAC, Western Interior RAC, Middle Kuskokwim Advisory Committee, KNA Tribal Gathering, other regional meetings in winters 2006-2007 and 2007-2008.
- Community meetings and school visits in 2006-2008 at various Kuskokwim River villages including: Chuathbaluk, Kalskag, Sleetmute, Stony River, Lime Village, Aniak, Crooked Creek, Red Devil.
- Presentations by AVCP and KNA college interns at an Intern Day sponsored by the U.S. Fish and Wildlife Service, Partners for Fisheries Monitoring Program in August 2006 and 2007.
- Oral presentation to scientific peers at Alaska Chapter of the American Fisheries Society meeting, Ketchikan, Alaska, November 2007.
- AYK SSI semi-annual progress reports submitted since July 2006.

Authors are submitting a draft copy of a detailed project report outlining the results of the study, prepared for the ADF&G Fishery Data Series. Additionally, one or two manuscripts are expected to be prepared for submission to peer-reviewed journals.

PROJECT DATA SUMMARY:

For adult distribution, run timing, and migration timing data: 1) Data collected are described in Chapter 1 of attached draft FDS, and include ATS receiver information for individual towers and aerial surveys, and ASL and tagging information for radio-tagged sockeye. 2) Receiver information and ASL information is stored in Excel files, and tagging information is stored in an Access database. 3) Custodian of data: Doug Molyneaux, ADF&G, Commercial Fisheries Division, 333 Raspberry Rd, Anchorage AK 99518, ph: 907-267-2397, fax: 907-267-2442, doug.molyneaux@alaska.gov. 4) Access limitations: collaborative agreement.

For juvenile habitat and growth data: 1) Data collected are described in Chapter 2 of attached draft FDS. 2) Beach seine data and scale data are stored in Excel files. 3) Custodian of data: Gregory T. Ruggerone, Natural Resource Consultants, Inc., 4039 21st Ave W, Suite 404, Seattle WA 98199, ph: 206-285-3480 ext. 209, fax: 206-283-8263, GRuggerone@nrccorp.com. 4) Access limitations: collaborative agreement.

APPENDIX:

Please see draft of report prepared for the ADF&G Fishery Data Series (attached).

Fishery Data Series No. YY-XX

Kuskokwim River Sockeye Salmon Investigations

Edited by

Sara E. Gilk

and

Douglas B. Molyneaux

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

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	$(F, t, \chi^2, \text{etc.})$
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. YY-XX

KUSKOKWIM RIVER SOCKEYE SALMON INVESTIGATIONS

Edited by
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b) Chapter 1 should be cited as: Gilk, S. E., D. B. Molyneaux, D. B. Young, and T. Hamazaki. 2009. Kuskokwim River sockeye salmon distribution, relative abundance, and stock-specific run timing [in] Gilk, S. E. and D. B. Molyneaux, editors. 2009. Kuskokwim River sockeye salmon investigations. Alaska Department of Fish and Game, Fishery Data Series No. YY-XX, Anchorage.

c) Chapter 2 should be cited as: Ruggerone, G. T., B. A. Agler, S. E. Gilk, D. B. Molyneaux, D. J. Costello, D. E. Orabutt, and D. B. Young. 2009. Habitat and growth of river-type sockeye salmon in the Kuskokwim watershed, Alaska. Prepared in cooperation with Natural Resources Consultants, Inc., [in] Gilk, S. E. and D. B. Molyneaux, editors. 2009. Kuskokwim River sockeye salmon investigations. Alaska Department of Fish and Game, Fishery Data Series No. YY-XX, Anchorage.

d) Chapter 3 should be cited as: Orabutt, D. E. 2009. Outreach and Capacity Building Associated with the Kuskokwim River Sockeye Salmon Investigations. Prepared in cooperation with Kuskokwim Native Association, [in] Gilk, S. E. and D. B. Molyneaux, editors. 2009. Kuskokwim River sockeye salmon investigations. Alaska Department of Fish and Game, Fishery Data Series No. YY-XX, Anchorage.

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

by

Sara E. Gilk
Douglas B. Molyneaux
Daniel B. Young
Toshihide Hamazaki

ABOUT THE AUTHORS

Sara Gilk and Douglas Molyneaux are fisheries biologists, and Toshihide Hamazaki is a biometrician with the ADF&G, Division of Commercial Fisheries, 333 Raspberry Rd, Anchorage, AK 99518-1599

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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 by the Alaska Board of Fisheries to allow directed commercial harvest on sockeye under a guideline harvest level; however, fundamental knowledge about distribution, abundance, and basic biology and ecology of sockeye salmon in the Kuskokwim River is lacking. Our aim was to begin addressing these data gaps by describing the spawning distribution, stock-specific run and migration timing, and relative abundance. We achieved these objectives by conducting radio tagging studies in 2006 and 2007. Results indicate that river-type sockeye salmon are far more important to the overall Kuskokwim River sockeye run than previously believed, particularly those spawning in the Holitna River basin which accounted for about 70 percent of the final destination of tagged fish. Other major contributors included the Stony River (lake-type), and Aniak River (river-type). River-type sockeye tend to have more volatile productivity than lake-type populations, so given the dominance of river-type fish in the Kuskokwim River, fisheries managers should anticipate highly variable annual returns that may be difficult to predict. 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: distribution, Holitna River, Stony River, Aniak River, Aniak Lake, Kogrukluk River, Telaquana Lake, Necons River, Two Lakes, stock-specific, run timing, migration rate, radiotelemetry, tagging, fish wheels, weirs, subsistence fishing, commercial fishing, salmon fishery management, Kuskokwim River, 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 1 million fish, with sockeye salmon *O. nerka* accounting for only about 70,000 (range 26,000 to 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 fishery for Kuskokwim River sockeye, which prompted the Alaska Board of Fisheries (BOF) in 2004 to formally establish a limited annual guideline commercial harvest level of 0 to 50,000 sockeye salmon. In accordance with the Alaska Sustainable Salmon Policy (5 AAC 39.222), fishery managers must use a precautionary approach in implementing this sockeye-directed fishery because of the lack of fundamental information about sockeye distribution, abundance, and run dynamics. Indeed, there are no current escapement goals established for sockeye salmon in the Kuskokwim River, and sockeye salmon generally have a low occurrence at the current array of tributaries where salmon escapements are monitored.

Of those tributaries monitored, the largest numbers of sockeye salmon occur at the Kogrukluk River weir located in the upper Holitna drainage, where annual escapements range from 1,700 to 60,000 fish (Liller et al. 2008; Figure 1.1). Kwethluk River ranks second with annual escapements ranging from a few hundred to 6,732 fish (Miller et al. 2007). Sockeye number fewer than 1,000 fish in the Tuluksak, George, Tatlawiksuk, and Takotna rivers. Like most of the Kuskokwim River drainage, neither the Kogrukluk nor Kwethluk Rivers have the large lakes that are more typically associated with significant sockeye production (Burgner 1991), so sockeye occurrence at these and the other monitored tributaries had been thought incidental. Most Kuskokwim River sockeye production was assumed to have been from Telaquana Lake, in the

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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 (ADF&G, unpublished data; Burkey and Salomone 1999).

Previously, there has been very little information on the distribution, relative abundance, or run timing dynamics of Kuskokwim River sockeye with which to support sustainable management. In this study, we used radiotelemetry in 2006 and 2007 to achieve the following objectives:

1. Describe the location and relative abundance of sockeye salmon spawning aggregates (stocks) in tributaries of the Kuskokwim River upstream of Kalskag (rkm 270), which constitute 5% or more of radio tags deployed in 2006 and 2007;

2. Estimate stock specific run-timing and stock-specific migration rates in the mainstem Kuskokwim River for the stocks identified in Objective 1.

3. Describe the relative importance of river-type versus lake-type sockeye salmon to total production of sockeye salmon in the Kuskokwim River based on the relative abundance of spawning adults

METHODS

CAPTURE AND TAGGING

Adult sockeye salmon were captured in 2006 and 2007 on the mainstem Kuskokwim River and fitted with radio and/or anchor tags (Figure 1.1). Captures were made at approximately rkm 270 using two fish wheels operated from early June to mid August, and fished 7 days per week in 2006 and 6 days per week in 2007, for about 9 hours each day during daylight hours. One fish wheel was located along the north bank and the other along the south bank, and each was equipped with a live box for holding fish prior to tagging. Throughout each day, the 2 to 3 person crew rotated between the 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 were immediately release. 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). 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 $\leq$ 400 mm mideye-fork length (MEF length) results in a higher probability of stomach rupture (Appendix 1.A); therefore, fish smaller 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; ADFG, Anchorage, unpublished data).

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

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were 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 radio-tagged sockeye salmon. Fish that were obviously injured, appear stressed, or were held more than 1 hour were not radio-tagged.

In addition to an internal radio transmitter, all radio-tagged 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 radio tagged 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, mid-eye-fork (MEF) length, condition of fish, and hold time. Immediately after tagging, fish were released.

In order to examine possible tag deployment biases (see Appendix 1.B), all other sockeye salmon were tagged with a uniquely-numbered 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 bank of capture, plus the adipose fin was removed as a secondary mark to allow for assessing tag loss. 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

Radio-tagged 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 at the lower end of major sub-basins 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 surveys included coverage of the mainstem Kuskokwim River, major tributaries, and many smaller tributaries. Purposes of aerial surveys were to: 1) locate radio-tagged fish that had not yet migrated into a spawning stream (including fates such as tag loss, handling mortality, or harvest), 2) locate tagged fish in spawning tributaries other than those monitored with tracking stations, 3) locate fish that ground-based stations failed to record, and 4) validate records from the ground-based stations. Two drainage-wide aerial 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 these surveys

bracketed the period when most sockeye salmon were likely to be on spawning grounds. 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 1-2 seconds. Once a tag was located, its frequency, code, and latitude/longitude were recorded by the receiver.

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

DATA ANALYSES

Findings from radio tag deployment were used to describe the spawning distribution of sockeye salmon upstream of Kalskag, to describe stock-specific run timings past the tagging site, and to describe stock-specific migration rates. "Stock" as used here either refers to spawning aggregates from large sub-basins such as the Holitna River or smaller drainages within thes 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 both radio- and anchor tag information (Appendix 1.B).

Spawning distribution was described by mapping the final destination of radio-tagged fish as determined from both ground-based receiver stations and aerial surveys. "Final destination" was defined as the farthest upstream location reported for a radio-tagged fish within any tributary of the Kuskokwim River. Radio-tags not found in a tributary stream were excluded. Fish that were detected downstream of the tagging site and that did not resume upstream migration (here, defined as passing the first upstream tracking site at Birch Tree Crossing, rkm 294; Figure 1.1) were also excluded. The proportion of radio-tagged sockeye salmon that returned to a particular tributary was calculated with adjustments to account for changes in the daily radio-tagging rate and fishing effort (Wuttig and Evenson 2002). Bootstrap techniques were used to estimate variance and confidence intervals (Sokal and Rohlf 1995).

Stock-specific run timings at the tagging site were described through examination of the tagging date for each radio-tagged salmon that successfully reached a spawning area (Mundy 1979, Merritt and Roberson 1986, Keefer et al. 2004). The mean and variance of the date of passage for each stock were calculated using methods described by Mundy (1979). 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 radio-tagged fish to travel between the ground-based receiver station at Birch Tree Crossing (Figure 1.1) 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. Additionally, migration rates of radio-tagged fish returning to the Holitna and Stony rivers were compared over a stretch of 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 run timing as estimated by catches in the fish wheel in both 2006 and 2007 (Figure 1.2). In 2006, 498 radio tags were deployed, the first on 14 June and the last on 15 August. In 2007, 488 radio tags were deployed, the first on 21 June and the last on 14 August. In 2006, 50% of radio tags were deployed in fish captured on the north bank and 50% were deployed on the north bank. In 2007, 48% of radio tags were deployed in fish captured on the north bank, 50% were deployed on the south bank, and 2% of deployed tags had incomplete information records. There was no difference between bank of origin in the ratio of tags reported at most tributaries, with the exception of Aniak River. In 2006, 70% of Aniak River fish were tagged on the south bank; in 2007, 60% of Aniak River fish were tagged on the south bank.

Fates were described for all radio-tagged fish (Table 1.1). In both 2006 and 2007, 3% of radio-tagged fish either lost their tags or were never located after tagging. In 2006, 9% of radio-tagged 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 radio-tagged fish was similar in 2006 and 2007 (Table 1.2; Figure 1.3). The most common age group in both years was age-1.3 (79% in 2006 and 72% in 2006), followed by age-1.2 (9% in 2006 and 16% in 2007). No 0-check fish were among those radio-tagged in 2006, but four were found among the 2007 deployments. (Zero-check fish undergo smoltification within a few months after emergence from the gravel, so their scales have no freshwater annulus or "check".) Females accounted for 41% and 40% of radio-tagged fish in the two years. Lengths of radio-tagged fish were generally similar in 2006 and 2007 (Figure 1.3).

DISTRIBUTION

Radio-tagged sockeye salmon primarily traveled to tributaries within the middle Kuskokwim River basin (Figures 1.4, 1.5). Based on the weighted distributions, Holitna River sub-basin accounted for 71% of the fish in 2006 and 70% in 2007, followed by the Stony River sub-basin with 15% in 2006 and 19% in 2007, and then the Aniak River sub-basin with 9% in 2006 and 8% in 2007 (Tables 1.3, 1.4). Smaller numbers of fish were tracked to the Holokuk (1 - 3% in each year), Oskawalik (< 1% - 1% in each year), and George (< 1% - 1% in each year) rivers. In 2006, one radio-tagged fish returned to Vreeland Creek and one to the Swift River drainage. No radio-tagged sockeye were found in the Kuskokwim River basin upstream of the Swift River drainage in either year.

Within the Holitna River sub-basin, radio-tagged 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, which accounted for 34% of the weighted Kuskokwim River distribution in 2006, and 25% in 2007. Also important were the Hoholitna (15% of fish in 2006 and 21% in 2007),

the Kogrukluk (15% in 2006 and 17% in 2007), and the Chukowan rivers (7% in 2006 and 6% in 2007). No radio-tagged fish entered Whitefish Lake.

Within the Stony River sub-basin, radio-tagged fish were tracked to locations in either mainstem Stony River or one of two lake systems (Tables 1.3, 1.4). Mainstem areas accounted for 5% of the weighted Kuskokwim River distribution in both 2006 and 2007. The Telaquana River/Lake drainage accounted for 6% in both years; and the Necons River/Two Lakes drainage accounted for 3% and 8%.

Within the Aniak River sub-basin, radio-tagged fish were found in both the mainstem Aniak River and various tributaries (Tables 1.3, 1.4). The majority were tracked to the mainstem Aniak River downstream of the confluence with the Salmon and Kipchuk rivers, which accounted for 6% of the weighted Kuskokwim River distribution in 2006, and 4% in 2007. The upper mainstem Aniak River upstream of the Salmon and Kipchuk rivers accounted for 3% of the fish in both years. Also important was the Kipchuk River drainage with 1% of the fish in both years. No radio-tagged sockeye salmon were tracked to Aniak Lake.

STOCK-SPECIFIC RUN TIMINGS

Migratory timing patterns of stocks past the Kalskag tagging site were similar in 2006 and 2007 (Figure 1.6). The median date of passage for Stony River radio-tagged fish was 3 July in 2006 and 2 July in 2007. The median date of passage for fish traveling to the Holitna River sub-basin was 5 July in 2006 and 7 July in 2007, and for Aniak River fish 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 the Stony and Aniak fish ($D = 0.339$, $P < 0.01$) and between Holitna and Aniak fish ($D = 0.250$, $P < 0.05$), but not between the Stony and Holitna fish ($D = 0.178$, $P = 0.075$). In 2007 there was a significant difference in run timing between Stony and Aniak fish ($D = 0.539$, $P < 0.001$) and between Stony and Holitna fish ($D = 0.372$, $P < 0.001$), but not between the Holitna and Aniak fish ($D = 0.167$, $P = 0.478$).

STOCK-SPECIFIC MIGRATION RATES

In both years, Aniak River fish traveled an average of 12.5 rkm/day in 2006 and 9.5 rkm/day in 2007 to travel from the Birch Tree Crossing start point to the ground-based receiver in the lower Aniak River (Table 1.5). Stony River fish traveled an average of 29.7 rkm/day in 2006 and 28.6 rkm/day in 2007 to migrate from Birch Tree Crossing to the receiver in the lower Stony River. Holitna River fish traveled fastest, passing the lower Holitna River receiver at an average rate of 37.0 rkm/day in 2006 and 31.3 rkm/day in 2007. Among Holitna River fish, fish tracked to the Hoholitna River traveled at 37.2 rkm/day and 31.8 rkm/day in 2006 and 2007, while those tracked to the Kogrukluk River traveled at 24.3 rkm/day in 2006 and 22.0 rkm/day in 2007. Among the Stony River fish, those tracked to Telaquana Lake traveled at a slower rate of 22.5 rkm/day and 22.4 rkm/day in 2006 and 2007.

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, Holitna River fish traveled at a 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 ($P < 0.05$), but not 2007.

DISCUSSION

TAGGING

The number of radio-tagged fish found downstream of the tagging site that 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 were nearly identical between the two years during June and early July (ADF&G, Anchorage, unpublished data). However, lower water levels and increased water clarity observed in June and July of 2007 may have increased stress (http://waterdata.usgs.gov/usa/nwis/nwisman/ ?site_no=15304000&agency_cd=USGS; ADF&G, Anchorage, unpublished data). 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

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 spawner distribution upstream of Kalskag in 2006 and 2007. 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), chum (Bue et al. 2008), and sockeye salmon (Appendix 1.A) and highlights the importance of this sub-basin to overall salmon production in the Kuskokwim River.

Due to the importance of the Holitna River to the overall Kuskokwim River sockeye run, the Kogrukluk River weir, located in the upper Holitna River drainage, may provide a useful site for managers to monitor sockeye 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 to 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 under the assumption that sockeye salmon in the system were incidental and likely not representative of the bulk of Kuskokwim River sockeye because of the lack of lake habitat typically associated with sockeye salmon (Burkey et al. 1999). In light of our findings, however, the Kogrukluk River may indeed be a reasonable index stream for monitoring sockeye escapement, and ADF&G is considering re-establishing an escapement goal at the weir as part of a response to growing interest in developing a directed commercial sockeye fishery.

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 only accounted for 18 to 20% of the

tributary spawners in 2006 and 2007; these included fish from the Stony and Holokuk rivers. Downstream of our study area, lake-type populations have been reported in the Kwethluk River (McPhee et al. *in press*), but may account for a small fraction of the annual Kwethluk River escapements (range 272 to 6,732; Miller et al. 2008).

Tributaries with no associated lake system accounted for 81 and 78% of the total tributary spawners in our study area in 2006 and 2007, 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 juveniles rear and over-winter after emergence 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 salmon with piscivorous juvenile stages (see Ruggerone et al., this manuscript).

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 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 radio tagged in the Kuskokwim River in 2006 and the incidence in 2007 was < 1%. Similarly, 0-check sockeye salmon account for 1% or less of the annual 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). Interestingly, there was a significant difference in the proportion of radio tagged 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. Since lake-type sockeye may not be as susceptible to changes in water level, freezing, desiccation, or changes in silt load, lake-type populations may be more stable in some climatic regimes. 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).

Kuskokwim River sockeye managers cannot necessarily apply knowledge gained elsewhere from lake-type populations as they may overestimate the productivity of the system. 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. *in press*). Thus, a fishery reliant on river-type sockeye should expect annual harvest levels to be variable. This high volatility is evident in the coefficient of variations (CVs) of annual sockeye 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 important than previously believed. These calculations were limited to escapements occurring between 2001 and 2008 when minimal commercial harvest occurred in the Kuskokwim River, and 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 abundance in the Kuskokwim River, an aggressive harvest strategy dependent on river-type sockeye is at risk of overexploiting the less productive populations and perhaps the entire run. The likely variability in productivity between river-type and lake-type populations requires monitoring escapements of both life history types.

Possible Colonization

No radio-tagged 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 passage has ranged from 0 to 60 fish. It is possible that these fish are strays from river-type Kuskokwim sockeye stocks, since Wood et al (2008) argues 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 may have been the primary colonists of new habitat following glaciation (Wood 1995), and genetics studies demonstrate less differentiation among river-type sockeye populations compared to lake-type populations implying that natal homing may be less precise (Gustafson and Winans 1999, Beacham et al. 2004). Future genetics studies could examine the validity of this hypothesis among Kuskokwim River sockeye salmon populations.

STOCK-SPECIFIC RUN TIMINGS

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 harvest to target one of these major stocks over another. Still, there were statistically significant differences between some of the major stocks, and the general run-timing pattern seen between stocks from radio-tags in 2006 and 2007 is consistent with the pattern seen with anchor tags in 2002 through 2006 (Appendix 1.C; Schaberg and Liller *in prep*).

Not withstanding the smaller sample sizes, it is interesting to note that in the anchor tag data some of the smaller stock groups, such as George and Takotna rivers, have markedly later run timings than the larger stocks. The population sizes in these smaller stocks number in the dozens to a few hundred fish. The later run timings seen in these smaller stocks could be a function of the fish being strays from one or more of the larger stocks. Baseline genetics sampling that is currently ongoing may ultimately address this hypothesis.

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 and Liller *in prep*). 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 number 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 km per day for Aniak and Holitna River fish. 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 between stocks in migration rates, 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 to 203). Again, concurrent tagging in District 1 and the Kalskag site would provide some resolution.

Our findings also provide an opportunity to resolve an issue lingering from previous tagging studies regarding the potential confounding effect of recovery time when comparing migration rates derived from anchor tag data. It is possible that a given recovery time following a tagging event would have more of a confounding effect for stocks closer to the tagging site than to stocks with more distant spawning areas. Our radio tag data allows editing out the recovery time by establishing a "start" point upstream of the tagging site beyond which fish are assumed to have recovered from the tagging event and resuming their upstream migration.

CONCLUSIONS AND RECOMMENDATIONS

- Both river-type and lake-type sockeye salmon life history ecotypes are important contributors to the annual Kuskokwim River sockeye run, though river-type appear to be the more dominant.

- The Holitna River basin was the single largest concentration of spawning sockeye salmon in the Kuskokwim River.

- Stock-specific run timing and migration rates at Kalskag show broad overlap between stocks.

- The Kogrukluk River weir is a good candidate stream to establish an escapement goal for river-type sockeye salmon.

- 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 total abundance estimate as will be needed to address issues of harvestable surplus and exploitation rate.

- If an expanded commercial fishery is pursued, managers need to better understand dynamics of sockeye salmon life history types.

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Table 1.1.—Fates of Kuskokwim River sockeye salmon radio-tagged at the Kalskag Fish Wheels in 2006 and 2007.

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

Table 1.2.–Age and sex information for Kuskokwim River sockeye salmon radio-tagged at the Kalskag Fish Wheels in 2006 and 2007.

	2006				2007			
Age	Females	Males	Unknown	Total	Females	Males	Unknown	Total
0.3	0	0	0	0	2	2	0	4
1.2	22	16	0	38	22	44	1	67
1.3	137	206	0	343	133	169	1	303
1.4	16	15	0	31	9	16	0	25
2.2	0	3	0	3	1	0	0	1
2.3	9	7	0	16	9	13	0	22
2.4	0	2	0	2	0	0	0	0
ND	18	44	3	65	17	47	2	66
Total	202	293	3	**498**	193	291	4	**488**

Table 1.3.–Distribution of radio-tagged sockeye salmon in the Kuskokwim River basin, 2006. Distribution proportions were adjusted to account for differences in daily tagging rates and fishing efforts.

Spawning Stream	Number of radio tags	Proportion of all spawners[a]	Percentile Limits (5th - 95th)
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 radio-tagged sockeye salmon in the Kuskokwim River basin, 2007. Distribution proportions were adjusted to account for differences in daily tagging rates and fishing efforts.

Spawning Stream	Number of radio tags	Proportion of all spawners[a]	Percentile Limits (5th - 95th)
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.– Movement rates (rkm/day) of Kuskokwim sockeye salmon radio tagged at the Kalskag Fish Wheels during 2006-2007 based on fish passage by ground-based tracking stations.

Tracking Station	Distance from Birch Tree Crossing tracking station (rkm)	2006			2007		
		Mean	95% CI	N	Mean	95% CI	N
Aniak River	29	12.5	2.1	36	9.5	2.1	27
Holitna River	204	37.0	1.0	262	31.3	0.9	221
Hoholitna River	252	37.2	2.0	52	31.8	1.6	61
Kogrukluk River	416	24.3	1.8	61	22.0	1.7	52
Stony River	249	29.7	1.9	60	28.6	1.8	75
Telaquana Lake	462	22.5	2.3	20	22.4	1.8	27
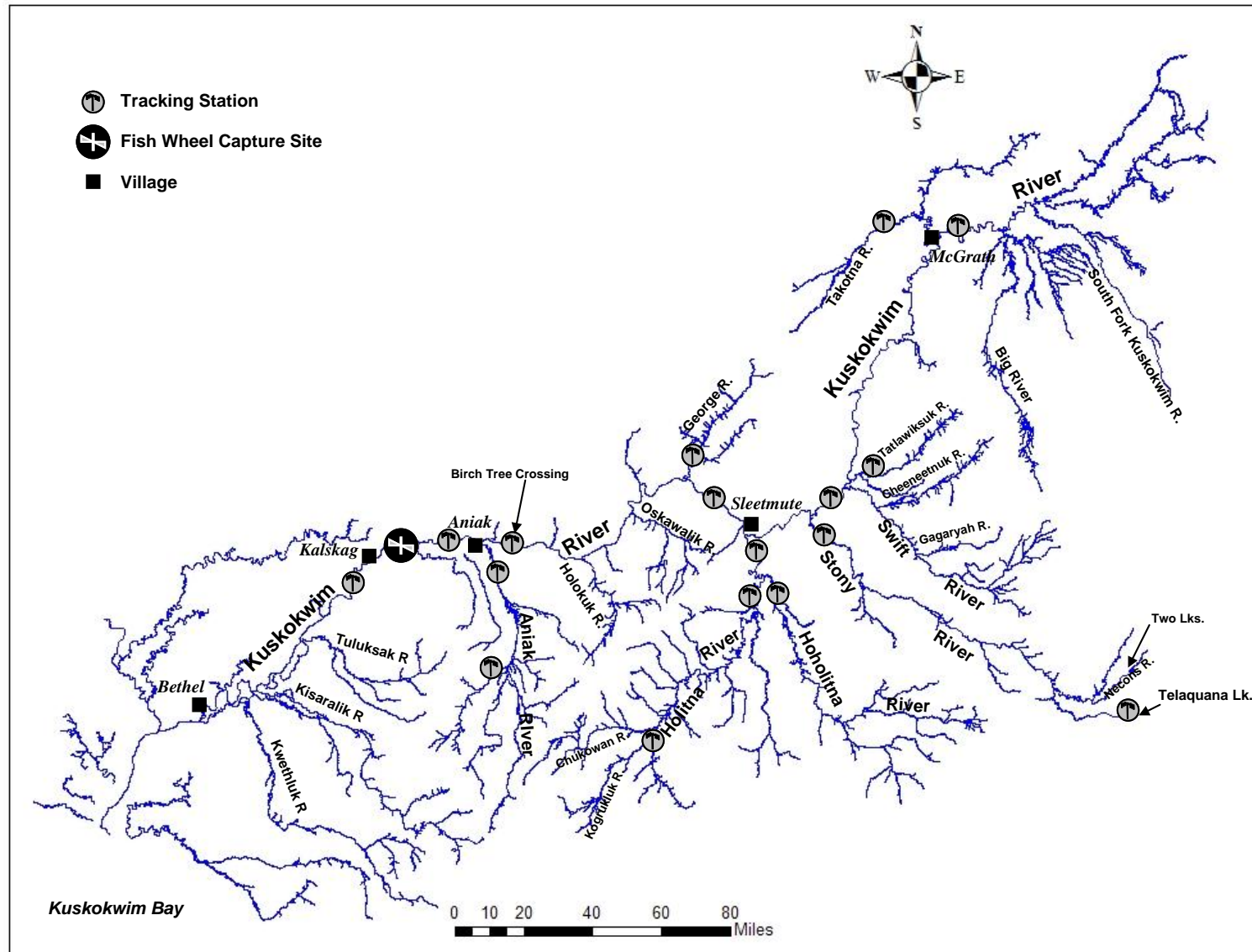
Figure 1.1.–Map of the Kuskokwim River showing tributaries, capture site, and ground-based tracking stations.
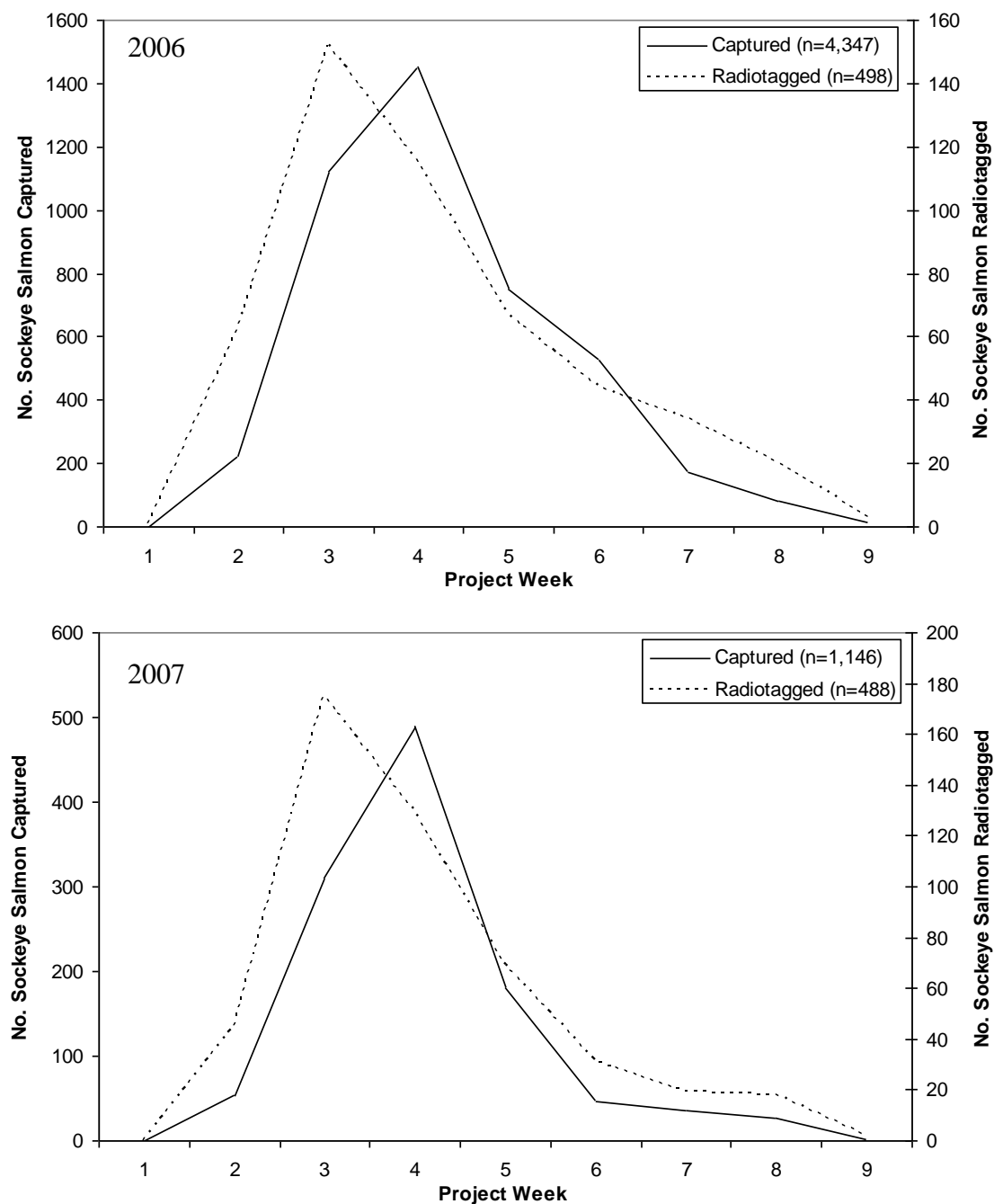
Figure 1.2.–Number of Kuskokwim River sockeye salmon captured and radiotagged by project week at the Kalskag Fish Wheels, 2006 and 2007.
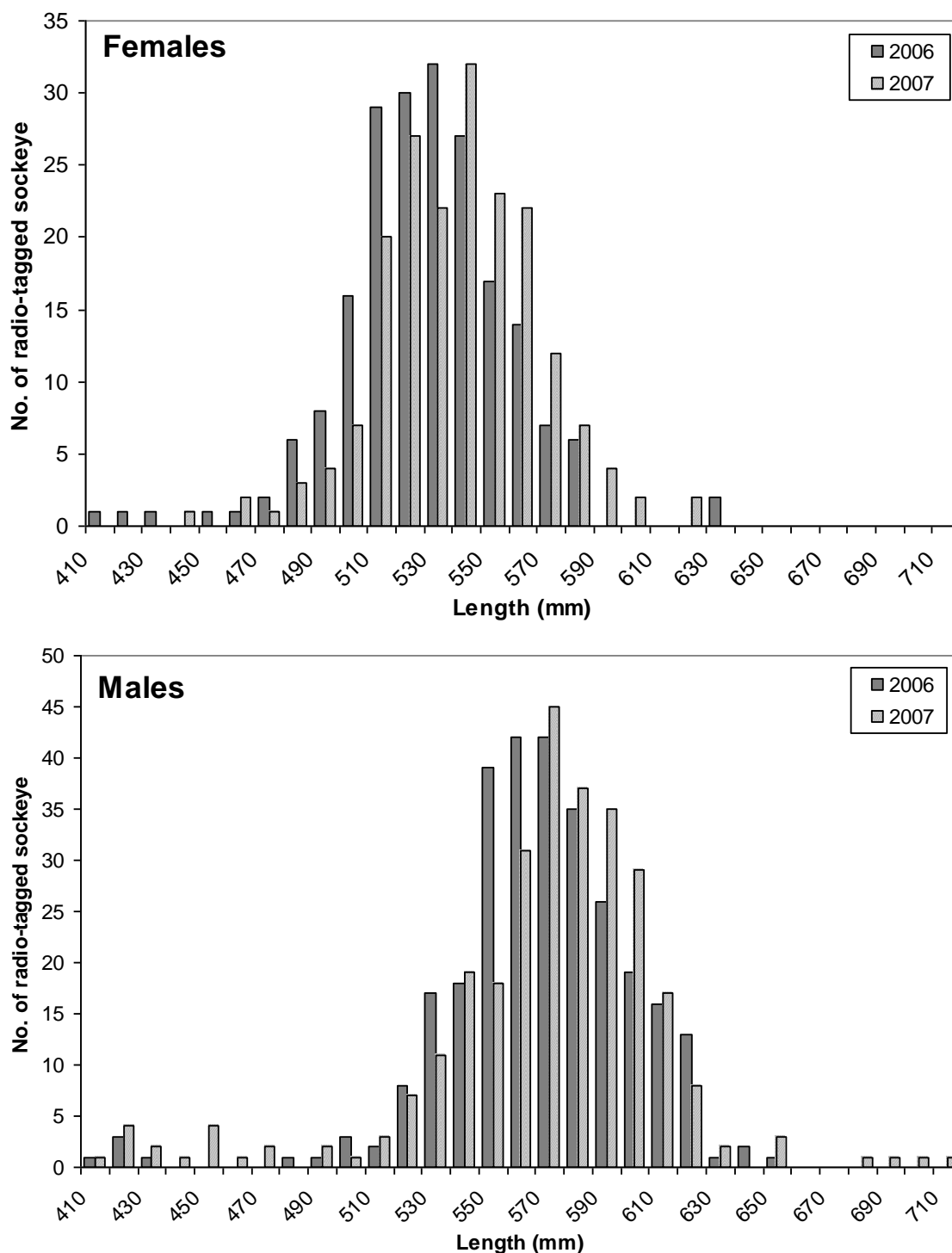
Figure 1.3.–Length distribution of female and male radio-tagged sockeye in 2006 and 2007.
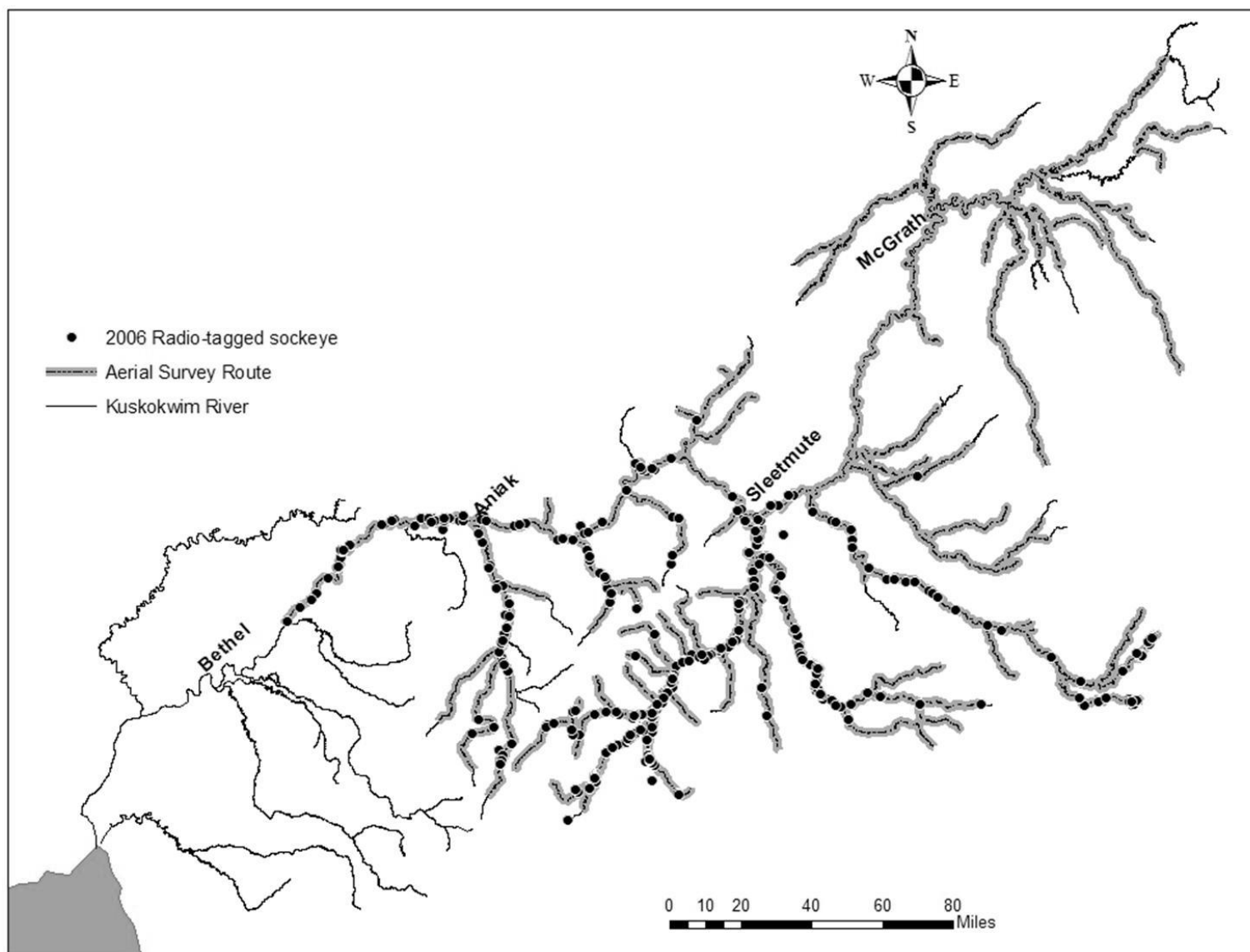
Figure 1.4.–Map of the Kuskokwim River drainage showing the approximate uppermost final locations of radio-tagged sockeye salmon and flight routes during aerial surveys in July, August, and September, 2006.
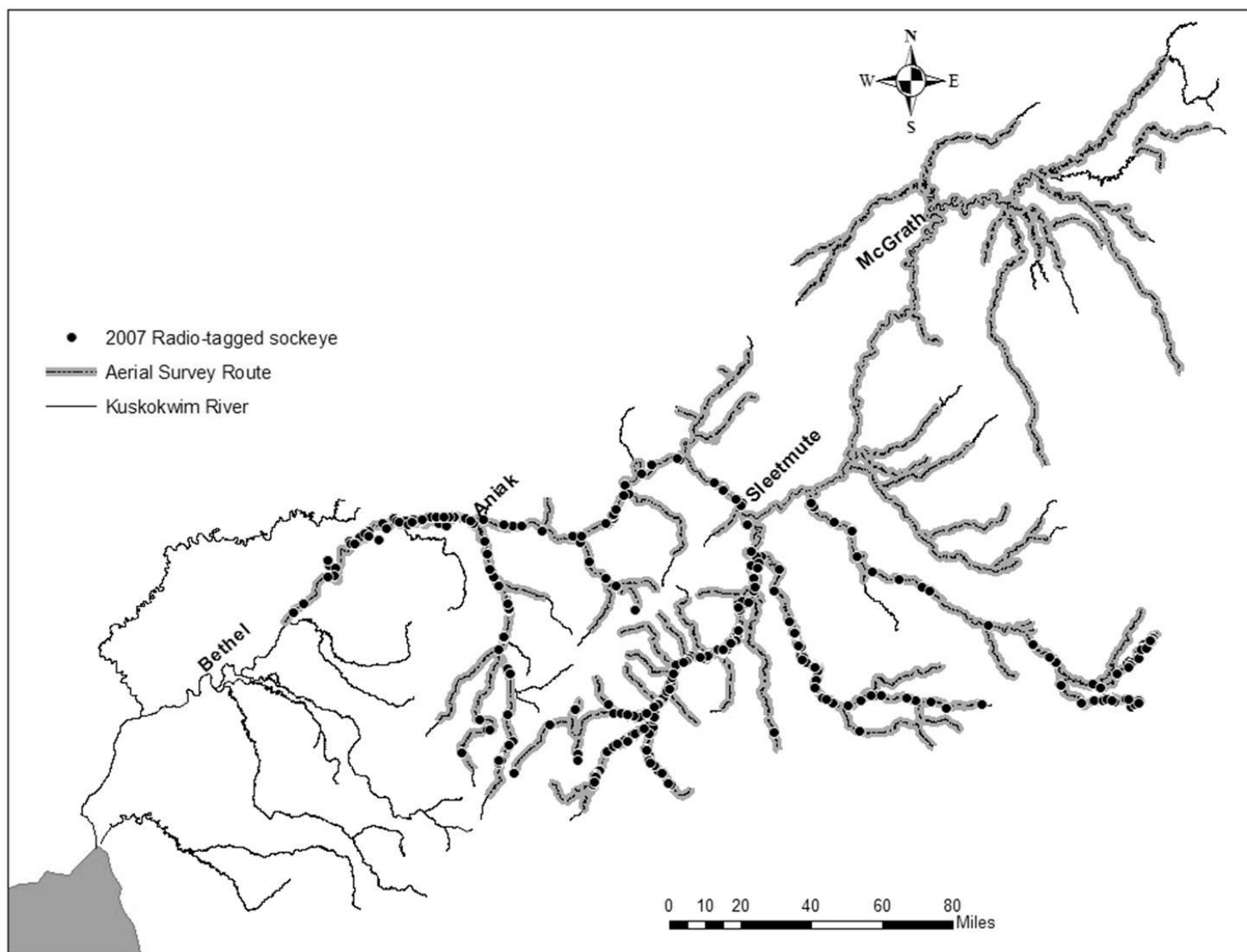
Figure 1.5.– Map of the Kuskokwim River drainage showing the approximate uppermost final locations of radio-tagged sockeye salmon and flight routes during aerial surveys in July, August, and September, 2007.
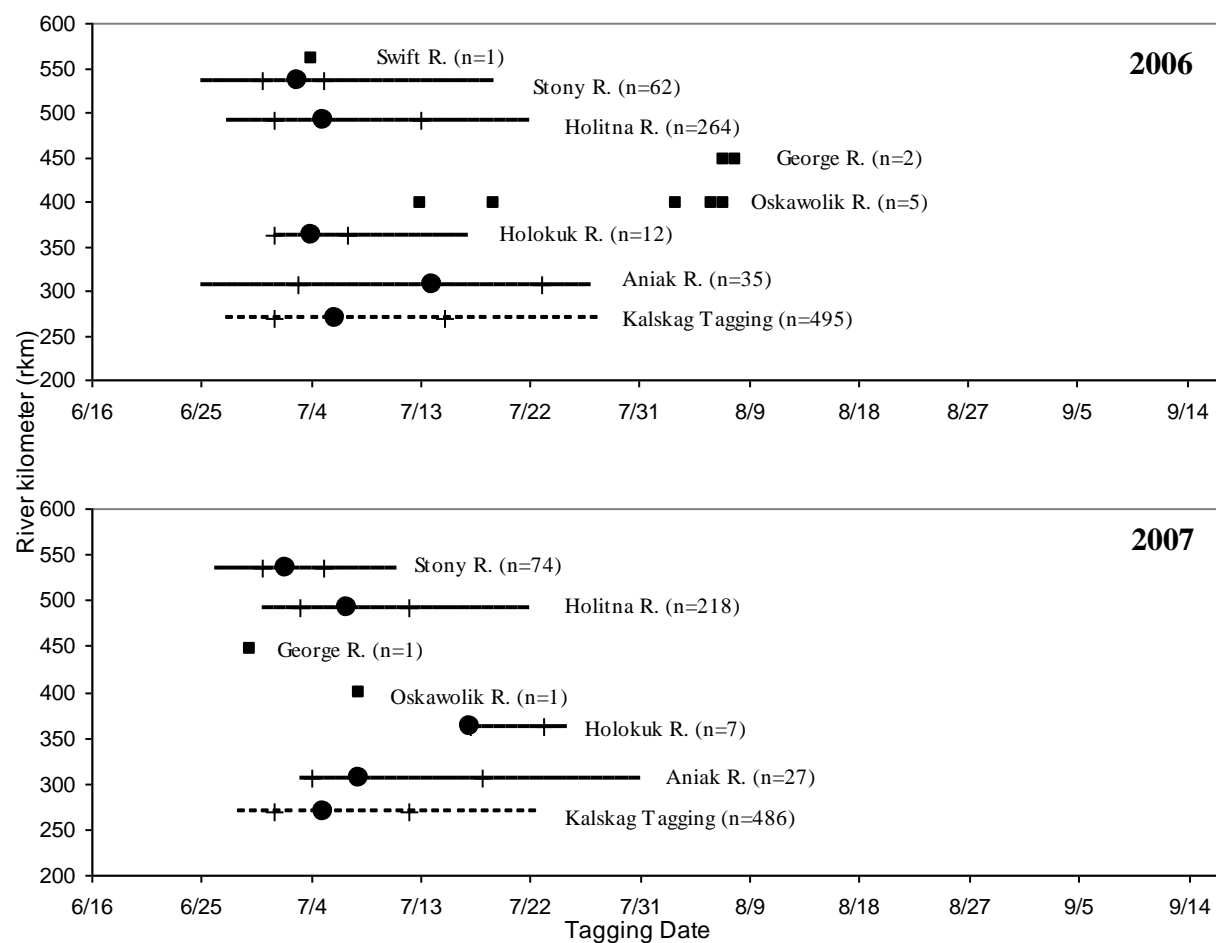
Figure 1.6.–Stock specific run timing for Kuskokwim River radio-tagged sockeye in 2006 and 2007, including median, quartile, 10th percentile, and 90th percentile dates.

APPENDIX 1.A.—2005 PILOT RADIOTAGGING STUDY

Introduction

In 2005, ADF&G and industry mounted a modest pilot project on Kuskokwim River sockeye salmon. Using funds provided 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. The results of this study gave some surprising insight into the biology of Kuskokwim River sockeye salmon, but were only a preliminary step in addressing the important data gaps that exist for Kuskokwim River sockeye salmon.

Objectives

The objectives for the 2005 feasibility study were to:

1) Determine the coarse scale geographic distribution of sockeye salmon spawning areas within the Kuskokwim River drainage upstream of Kalskag;

2) Determine the coarse scale 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 a basin-wide sockeye salmon radio telemetry project;

4) Provide baseline samples for genetic stock identification of sockeye salmon spawning population.

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 A.1). Tagging was concentrated into three tagging periods in June and July (Table A.1). A total of 70 tags were deployed 24 June to 1 July in order to correspond with the peak of sockeye passage. In the first tagging period, efforts were made to evaluate effects of tag size and holding time; in the remaining tagging periods, efforts were made to minimize holding time to less than one hour.

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 42mm), model F1840 (17 x 51mm), and model F1845 (19 x 51mm). To best evaluate tag sizes, smaller (< 550 mm MEF length) fish were initially targeted to be tagged with model F1845 tags and larger (> 600 mm MEF length) fish 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 radio-tagged. 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 radio-tagged 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, mid-eye 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.

Radio-tagged sockeye salmon were tracked using a network of ground-based tracking stations already established for Chinook salmon radiotelemetry studies (Figure A.1; Stuby 2005). Three additional stations were added in 2005: 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 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 along the mainstem Kuskokwim River and in major tributaries to identify and locate the fate of radio-tagged fish. In 2005, aerial tracking surveys were conducted in July, August, and September. 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 occurred periodically near the capture/release 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 conducted in Telaquana Lake from periodically from July to October to document movement of tagged sockeye salmon in that system.

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 address for reporting tag recoveries and for entry into the lottery.

Results and Discussion

Of 100 sockeye salmon radiotagged in 2005, 70 fish were radiotagged from 24 June to 1 July, 19 were tagged from 12 to 14 July, and the remaining 11 were tagged on 21 and 22 July (Table A.1). Of the radio tags deployed, 53 were deployed in fish captured on the north bank, 39 were deployed in fish captured on the south bank, and 8 were deployed in fish caught in gill nets. One fish was tagged and recaptured; the radio tag was removed from this fish and redeployed during the following tagging period. All model F1835 and F1845 radio tags were deployed during the first tagging period.

Hold Time

Of 92 sockeye salmon captured and radiotagged from fish wheels, 8 were tagged immediately upon capture, 18 were held in live boxes no more than 1 hour, 26 were held no more than 2 hours, 15 were held no more than 4 hours, 18 were held no more than 6 hours, and 7 may have been held more than 6 hours. Although the exact holding time of each fish was unknown, there appeared to be an effect of approximate holding time on upstream migration (Figure A.2). Average travel time to the first upstream tracking station (36 rkm from the tagging site) was 2.9

days for fish tagged immediately upon capture, 3.6 days for fish held no more than 1 hour, 5.9 days for fish held no more than 2 hours, 4.7 days for fish held no more than 4 hours, 4.2 days for fish held no longer than 6 hours, 3.6 for fish held more than 6 hours, and 5.3 days for fish caught in drift gillnets. Sample sizes are small; however, in future years efforts should be made to reduce hold time to less than one hour. Tagging immediately upon capture would be the preferred method for radiotagging sockeye salmon, but may not be practical due to lack of a dedicated crew for sockeye tagging. 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

A total of 40 model F1845 radio tags were deployed during the first tagging period in fish ranging between 510 and 610 mm MEF length, with an average length of 559 mm. Smaller (< 550 mm) fish were initially targeted for tagging with the F1845, but the preferred size was increased when taggers reported a high risk of stomach rupture in fish < 550 mm. Of the 40 sockeye salmon tagged with the F1845, 38 fish (95%) successfully continued migration upstream. Two fish (5%) of 550 and 610 mm length 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.   The maximum tag life (days from date of deployment to date of final detection) was 101 days, and the average was 66 days excluding fish that went downstream.

Fifty model F1840 radio tags were deployed during the first, second, and third tagging period in fish ranging between 415 and 660 mm MEF length, with an average length of 554 mm. Of the 50 tagged sockeye salmon, 41 fish (82%) successfully continued migration upstream. Nine fish (18%) ranging in length between 450 and 570 mm (average length 523 mm) did not resume upstream migration. Taggers reported tight insertions of F1840 tags in some fish smaller than about 450 mm MEF length. The maximum tag life was 109 days, and the average was 65 days excluding fish that went downstream.

Ten model F1835 radio tags were deployed in the first tagging period in fish ranging between 570 and 625 mm mideye-fork length, with an average length of 605 mm. Larger (> 600 mm) fish were targeted for tagging with the F1835. Of the 10 sockeye tagged with F1835 tags, 9 fish (90%) successfully continued migration upstream. One fish (1%) with a length of 595 mm did not resume upstream migration. Taggers did not report tight insertions with the F1835 radio tags. The maximum tag life was 97 days, and the average was 67 days excluding fish that went downstream.

Of the three tags tested in 2005, the model F1840 gave the best combination of expected tag life and small tag size. Though the F1845 tag has the largest battery and thus the longest expected tag life, it was too large to tag many sockeye salmon in this study. Because of concern by taggers about the possibility of rupturing stomachs, this tag should not be used on smaller (< 550 mm) fish. Based on length data collected at the Kalskag and Aniak fish wheels in 2002 and 2003, 49.2% and 32.7% of sockeye salmon were < 550 mm (ADF&G, Anchorage, unpublished data). In order to avoid excluding a high proportion of sockeye, tags smaller than the F1845 should be used. Although tight insertions were reported in fish < 450 mm using the F1840, with care fish between 400-450 mm can be successfully tagged. Based on length data from 2002 and 2003, fish < 400 mm constituted only 3.9% and 6.4%, respectively, of the total catch at the

Kalskag and Aniak fish wheels (ADF&G, Anchorage, unpublished data). Though the F1835 tag gives the best option for tagging fish < 400 mm, it has the shortest tag life of all of the tags used. While the maximum tag life was similar to the F1840 and F1845 in 2005, there are concerns that tags deployed early in the season would not remain active through the final boat and aerial tracking surveys in September or October.

Distribution

Of the 84 radio-tagged sockeye salmon that successfully resumed upstream migration and entered tributary streams, 11 returned to the Aniak River, 1 returned to the Holokuk River, 51 returned to the Holitna River, 20 returned to the Stony River, 1 returned to the Swift River (Figure A.3). Four tagged fish were last detected in the mainstem 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 lowest tracking station and did not resume upstream migration, and 7 fish were not detected after tagging and had unknown fates.

Information from this feasibility study suggests that many sockeye salmon in the Kuskokwim River drainage upstream of Kalskag return to rivers with no connection to lake habitat. Of the locations where sockeye salmon were found, only the Aniak and Stony River fish have access to substantial lake habitat for juvenile rearing typical to other systems (e.g. Bristol Bay; Burgner 1991). This is surprising in part because commercial catch sampling since 1984 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 ("river-type" sockeye salmon), even though river-spawning sockeye 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 one 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 two 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 one Swift River fish was age-1.3. The overall age composition in radio-tagged sockeye salmon were similar to age compositions seen in commercial catch samples in 2005 (Molyneaux and Folletti 2005).

Only 29% of radio-tagged 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 taggers, or to overall 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.

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 1 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 battery life and small tag size for radiotagging Kuskokwim River sockeye salmon. However, fish < 400 mm MEF length should not be tagged because of increased incidence of stomach rupture. This is expected to exclude < 7% of the sockeye captured at the Kalskag fish wheels in a full-scale study.

- 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 populations in other systems as they may overestimate 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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Table 1.A.1.—Summary of sockeye salmon tagged for each period in north or south bank fish wheels or drift gillnets by tag model at the Kalskag fish wheels in 2005.

	North Bank			South Bank			Drift Gillnet			
	F1835	F1840	F1845	F1835	F1840	F1845	F1835	F1840	F1845	Total
Period 1 (24 Jun - 1 Jul)	7	9	21	1	9	15	2	2	4	70
Period 2 (12 - 14 Jul)		9			10					19
Period 3 (21 - 22 Jul)		7			4					11
TOTAL	7	25	21	1	23	15	2	2	4	100

Figure 1.A.1.—Map of the Kuskokwim Area indicating escapement monitoring projects, fish wheel tagging site, and radiotracking stations, 2005.
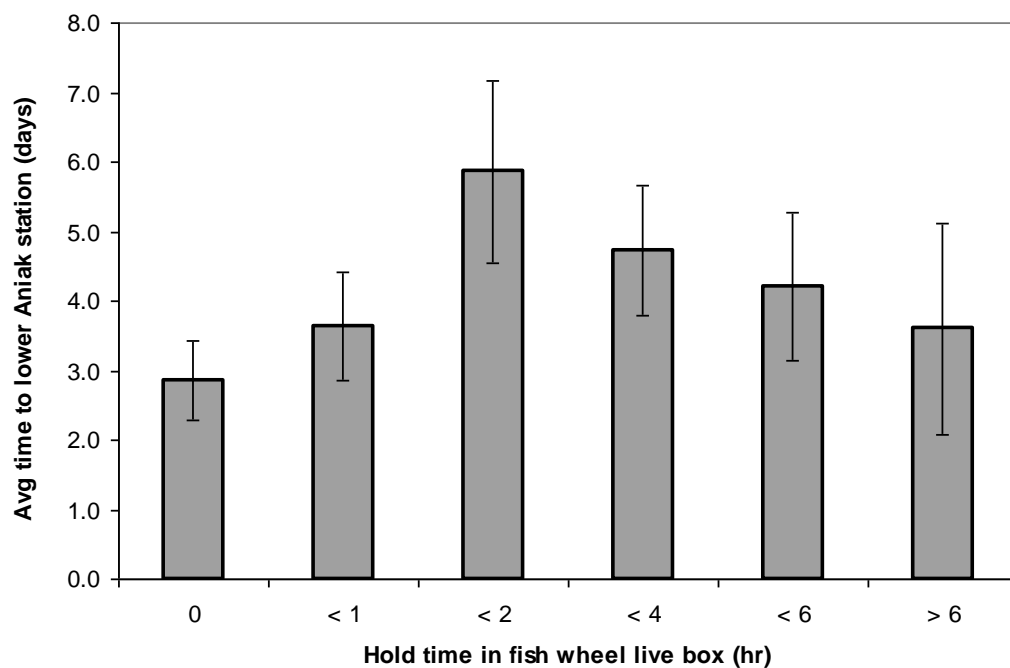
Figure 1.A.2.—Average migration rate to first station upstream of tagging sites for radio-tagged sockeye salmon held in fish wheel live boxes, 2005. Error bars indicate 90% confidence intervals.
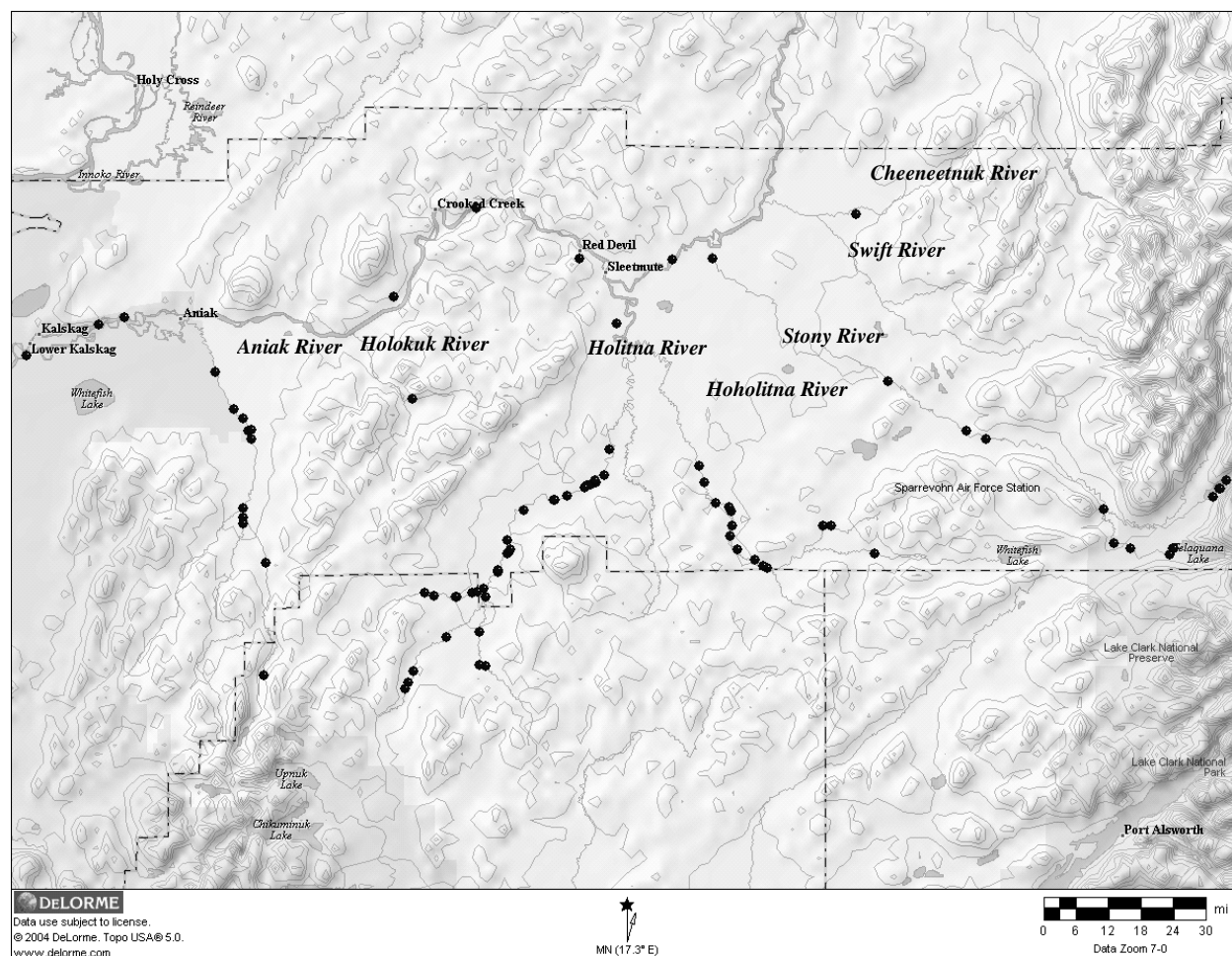
Figure 1.A.3.—Final locations of radio-tagged Kuskokwim River sockeye salmon tagged during the 2005 feasibility study. Tags were deployed during three tagging periods in June and July, and aerial tracking surveys were flown in July, August, and September.

APPENDIX 1.B.—EXPLORATION OF ABILITY TO PROVIDE TOTAL ABUNDANCE ESTIMATES FOR KUSKOKWIM RIVER SOCKEYE SALMON

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. One of the requirements for an unbiased estimate is that either 1) every fish has an equal probability of being marked during the first sampling event, 2) every fish has an equal probability of being recaptures during the second sampling event, or 3) marked fish mix completely with unmarked fish between sampling event. 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- 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 radio-tagged and anchor-tagged 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. wheel - 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:

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

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.

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 (Table B.1). At Kogrukluk River weir, 59,773 fish were observed including 380 radio- or anchor-tagged sockeye. Beach seining in Telaquana River resulted in a catch of 1,757 sockeye salmon, of which eleven 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 ($\chi^2 = 0.003$, df = 1, P = 0.96), suggesting the fish had an equal probability of recapture at the two recovery sites, and that our study design was not in violation of at least one condition required for an unbiased two-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 B.1). While we acknowledge limited diagnostic capacity to bolster confidence in these estimates our methodology did appear to perform adequately.

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 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 510,540 and 173,791 (Table B.2). We estimate an annual maximum exploitation rate of 10% in 2006 and 22% in 2007 if the current guideline harvest levels are met. 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 B.1). However, since abundance of sockeye salmon in the Kuskokwim River is far less than in Bristol Bay, there may not be adequate numbers of fish available for harvest to support an expanded commercial fishery. Furthermore, it would be essential for managers to better understand the dynamics of both river- and lake-type sockeye 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 significantly between 2006 and 2007, partially due to the near record sockeye 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. Given the exploitation rates calculated here, the Board of Fisheries adoption of a directed commercial sockeye salmon fishery of up to 50,000 fish may be conservative in reference to historical harvest numbers. There may be some room to expand sockeye salmon commercial fisheries in order to provide further economic opportunities to area residents; however, enthusiasm for a sockeye directed commercial fishery should be tempered with the understanding that total inriver abundance of Kuskokwim River sockeye salmon may at best approaches a few hundred thousand fish. In addition, 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 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 (Kogrukluk River weir) and Stony (Telaquana Lake) drainages for estimating Kuskokwim River sockeye salmon abundance while still incorporating both life history types.

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Table 1.B.1.—Abundance estimation for Kuskokwim River sockeye salmon using the Chapman estimator (Seber 1982) and parametric bootstrap estimates of confidence intervals (Quinn and Deriso 1999).

Year		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

Table 1.B.2.—Calculations of maximum exploitation rates in 2006 and 2007 for Kuskokwim River sockeye salmon if the 2004 Board of Fisheries guideline harvest level of 50,000 was met.

Run Component	Method	Year	
		2006	2007
Harvest			
Subsistence		37,300	37,600
Commercial		12,618	703
Sport		245	238
Total		50,163	38,541
Escapement			
Mainstem upstream Kalskag	Radiotelemetry	445,860	124,336
Kwethluk	Weir	6,732	5,262
Kisaralik	Estimate	6,800	5,300
Tuluksak	Weir	985	352
Total		460,377	135,250
Total Abundance		510,540	173,791
Annual exploitation (Maximum)		10%	22%
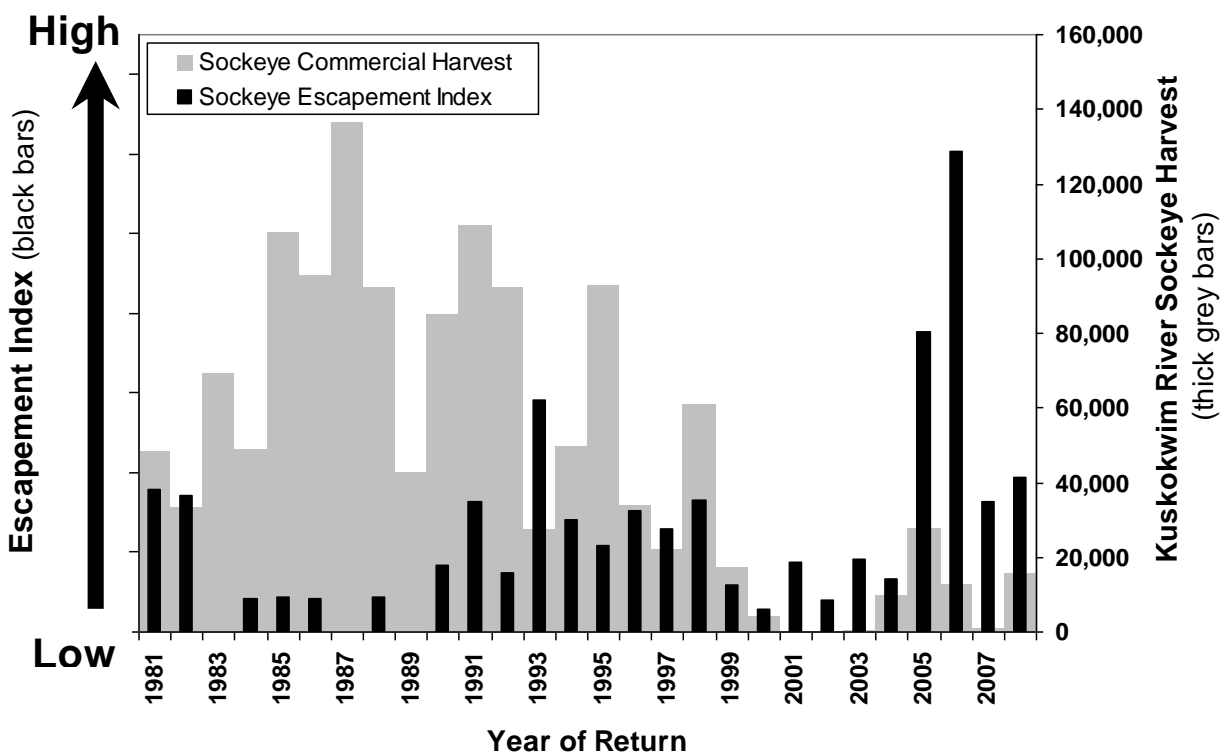
Figure 1.B.1.—Annual escapement index and commercial harvest of Kuskokwim River sockeye salmon. Escapement indices are based on annual Kogrukluk River weir sockeye passage.

APPENDIX 1.C.—HISTORICAL KUSKOKWIM RIVER SOCKEYE SALMON STOCK TIMING
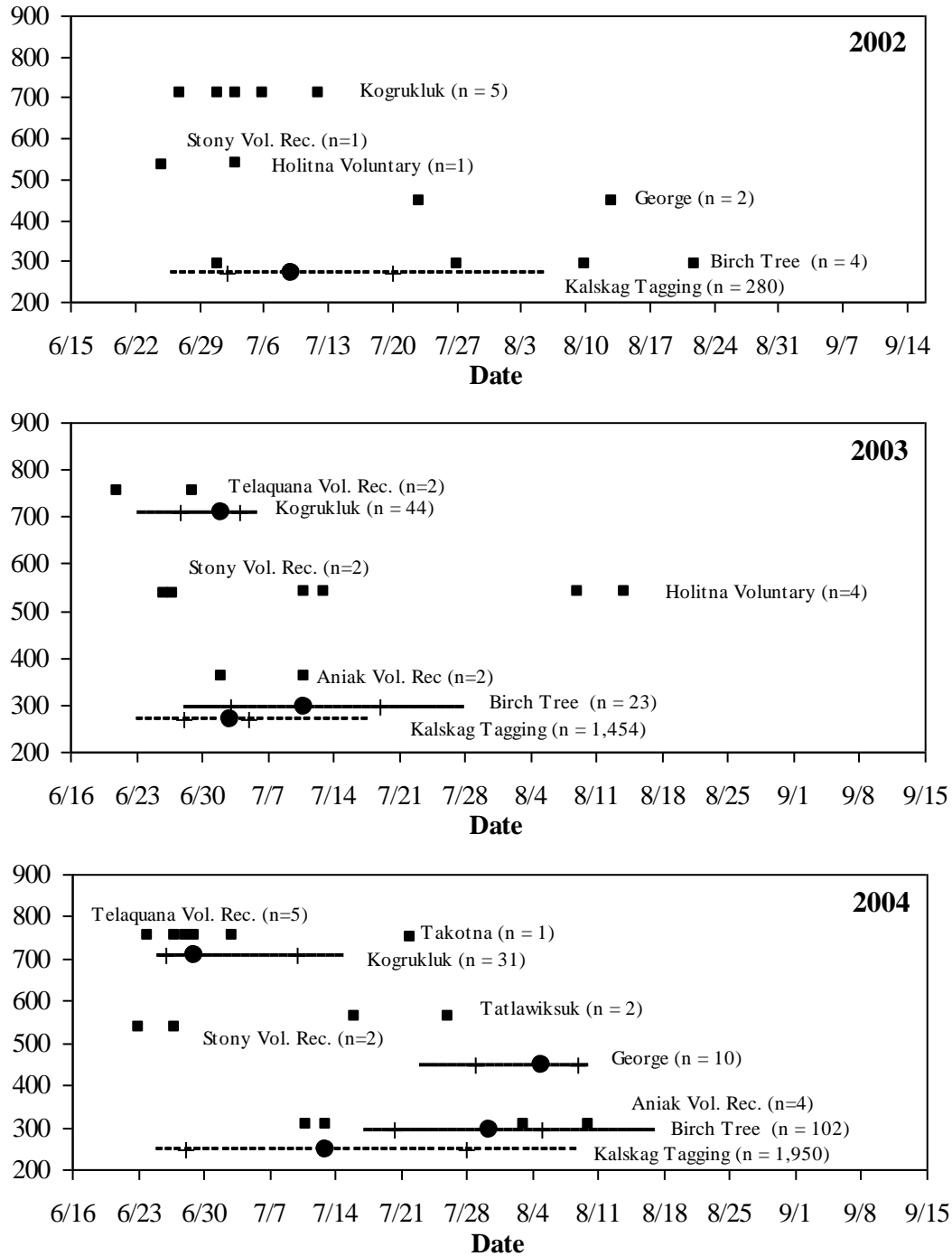
Figure 1.C.1.—Kuskokwim River sockeye salmon stock timing at various tributaries, 2002-2004, including median, quartile, 10th percentile, and 90th percentile dates. Estimates are based on anchor-tagged fish.

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Figure 1.C.2.—Kuskokwim River sockeye salmon stock timing at various tributaries, 2005-2007, including median, quartile, 10th percentile, and 90th percentile dates. Estimates are based on anchor-tagged fish.

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

by

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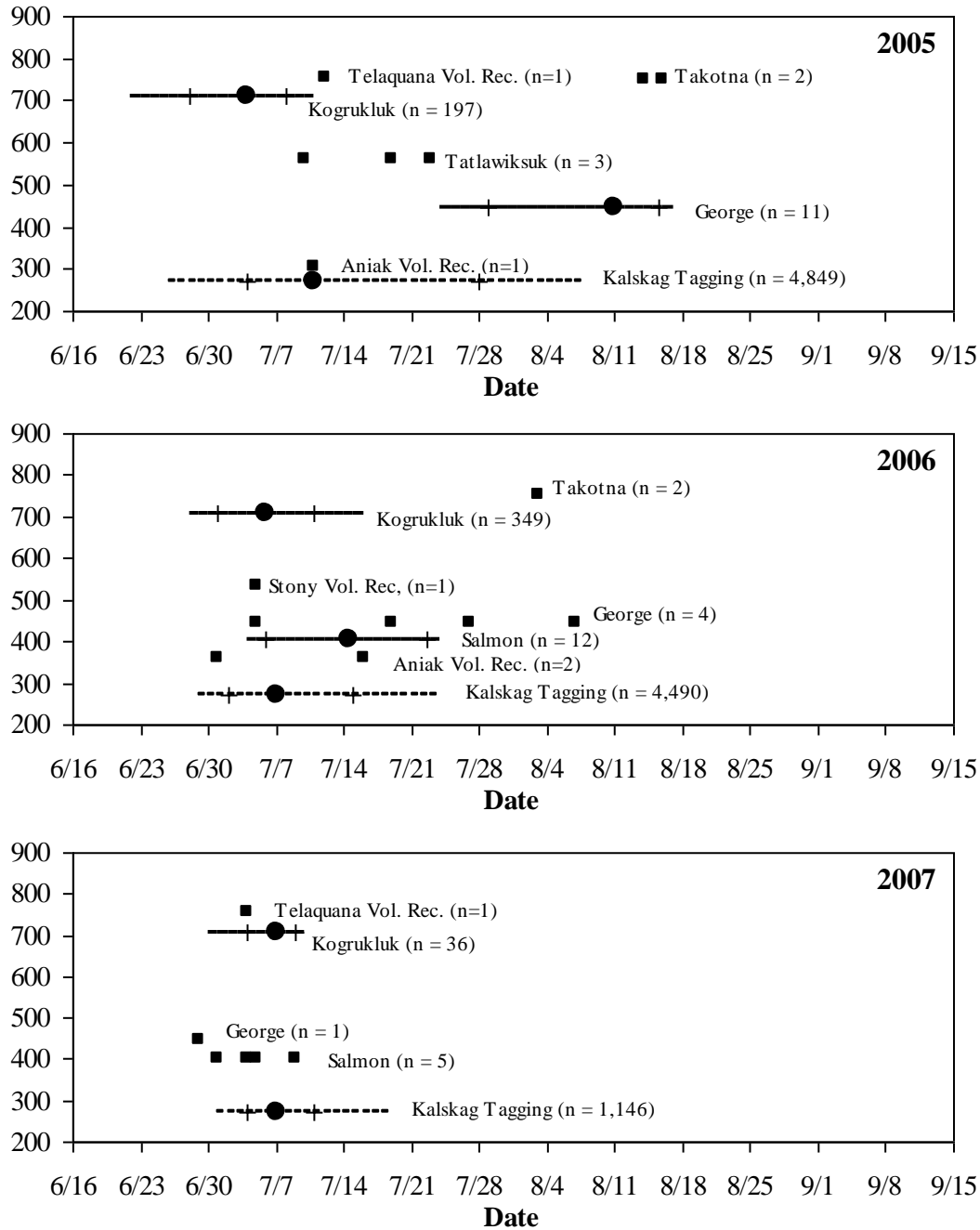Sara E. Gilk
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PROJECT SPONSORSHIP

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ABSTRACT

The Kuskokwim River supports a large population of sockeye salmon that inhabit riverine habitats for one year 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. Subyearling sockeye salmon were relatively abundant from late June through early August in the Kogrukluk River and during mid-July in the lower Holitna River, 2006. During June and July, catch per river-seine set (CPUE) was significantly greater in lentic slough habitats compared with flowing side channel and mainstem habitats. CPUE of sockeye salmon declined during late August and September when water level was low and slough habitats were reduced in size or dewatered. Presumably many sockeye salmon migrated downstream and overwintered in habitats associated with the mainstem Kuskokwim River rather than remain in habitats near the spawning grounds, e.g., Kogrukluk River. Average length of subyearling sockeye salmon in the Kogrukluk River increased from approximately 32 mm in late June to 50 mm in early August, then length remained stable as catches declined in late summer. Sockeye salmon length in the lower Holitna River was approximately 8-13 mm greater than sockeye salmon in the Kogrukluk River, which is approximately 180 km upstream. Sockeye salmon inhabiting mainstem habitats were significantly longer than those in side channel and slough habitats. These data suggest that juvenile sockeye salmon were actively migrating downstream as they grew older and larger. Habitats occupied by sockeye salmon that apparently emigrated out of the Kogrukluk and Holitna rivers during late summer and fall were not identified.

Approximately 82% of the variability in length of juvenile Kuskokwim sockeye salmon was explained by the geometric mean regression of scale radius on fish length. This relationship was similar to that for juvenile sockeye salmon from Chignik (Alaska Peninsula), suggesting that the scale-length relationship could be applied to adult sockeye salmon scales collected throughout the Kuskokwim watershed. Sockeye salmon lengths at the end of the first year in freshwater (FW1) and at the end of spring smolt growth (freshwater and estuarine growth) were back-calculated from 1,088 adult salmon scales collected from 16 watersheds during 2005-2007 (smolt years 2002-2004). Mean back-calculated length at the end of the first growing season ranged from 81 ± 2.3 mm (Two Lakes in Stony River watershed) to 108 ± 1.4 mm in Telaquana Lake (upper Stony River); whereas, mean length at the end of the spring smolt period (FW1 & FWPL) ranged from 96 ± 2.3 mm (Salmon River in upper Aniak River) to 117 ± 1.3 mm in Telaquana Lake. These lengths probably over-estimate mean length of juveniles in those watersheds because the estimated lengths were based on adult salmon that have likely undergone size-selective mortality that removed smaller fish. Telaquana Lake produced the largest juvenile sockeye salmon in the Kuskokwim watershed and lake-rearing sockeye salmon were significantly longer than sockeye 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.

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, river-type sockeye 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 or two years in a lake before emigrating to the ocean. Recent radio telemetry research (Gilk et al. 2009) indicated that most Kuskokwim sockeye salmon 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, know 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, the relatively low abundances of river-type and sea-type sockeye salmon compared with lake-type salmon across the Pacific Rim (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 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.

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 its major upriver tributary, the Kogrukluk River (Figure 2.1), during June through September 2006. The Holitna River is known to support river-type sockeye salmon (Baxter *Undated*, 1979) and up to 38,000 adult sockeye salmon per year have been counted at the Kogrukluk weir (Shelden et al. 2005). 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 radio-tracked to tributaries throughout the watershed (see Gilk et al. 2009) or sampled at weirs and projects during 2005-2007.

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

Habitat Use by Sockeye Salmon:

Hypothesis: Juvenile sockeye salmon and other juvenile salmonids randomly utilize river habitat types in the upper and lower Holitna River.

Hypothesis: 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.

Hypothesis: 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:

Hypothesis: 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.

Hypothesis: Sockeye 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 approximately 710 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 (Shelden et al. 2005, Gilk et al. 2009), whereas little, if any, spawning occurs in the lower Holitna River (few gravel areas). Sampling occurred from late June 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. 2006). 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 (see Appendix photos). 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 large water containers. 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, which was a wide (~150 m) low gradient river (see Appendix photos). 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 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 1) some adult scales were resorbed along the outer edge, and 2) allometry of scales and salmon length changes from juvenile to adult life stages (Fisher and Pearcy 2005). Therefore, as recommended by Fisher and Pearcy (2006), 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 a fish wheel at Kalskag (rkm 270; Figure 2.1), then live-released after tagging with an esophageal radio transmitter (Gilk et al. 2009). Spawning

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

area of tagged salmon was determined by aerial surveys and by remote receivers located in select drainages. 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 station 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 weirs and sonar stations 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, such as 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 & 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 underestimate variability in size.

COMPARISON OF KUSKOKWIM SOCKEYE GROWTH WITH OTHER STOCKS

Adult sockeye salmon were randomly sampled from the Kalskag fish wheel catch (Gilk et al. 2009); 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 sampled from seven other watersheds in Alaska (Kvichak, Egegik, Nushagak District, Black Lake, Kasilof, Kenai, Coghill) during the past 30-40 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 (FWPL) 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 three salmon per set during late August through late September (Figure 2.3). No yearling sockeye salmon were captured indicating most yearling 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 (Figure 2.4; Table 2.1) (g.m. = 4 fish; two factor ANOVA: df = 2, 62; F = 11.415, P < 0.001). 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 Chinook salmon per set in late June to 13.7 Chinook salmon 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 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 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 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, juvenile grayling and pike) peaked in late July (Figure 2.3), and there was no difference in CPUE between habitats (Table 2.1). No rainbow trout and only four char 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 fry were captured, sockeye 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 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, grayling, 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 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 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 were captured in the Holitna River for calculation of mean size.

SOCKEYE SALMON LENGTH-SCALE RADIUS RELATIONSHIP

Juvenile sockeye 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):

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

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 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 (see below) using the two models, sockeye 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 and areas within the Kuskokwim watershed. These areas ranged from the Kwethluk River in the lower watershed (~190 rkm from ocean) to Telaquana Lake in the upper watershed (~790 rkm from ocean). Juvenile sockeye salmon lengths were estimated 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. The following text 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 (Two Lakes in Stony River watershed) to 108 ± 1.4 mm in Telaquana Lake (upper Stony River) when samples from all years were combined (Figure 2.10). Mean length of sockeye salmon at the end of the spring smolt period (FW1 & FWPL) ranged from 96 ± 2.3 mm (Salmon River in upper Aniak River) to 117 ± 1.3 mm in Telaquana Lake (Figure 2.10). Estimated 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 spawning along the mainstem Kuskokwim River primarily upstream of Kalskag. 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 below).

Growth of juvenile sockeye salmon was compared between Kuskokwim watersheds 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, 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 of Telaquana Lake sockeye salmon during the smolt migration period was less than other stocks in 2007 but typical of other stocks in 2006.

Back-calculated lengths of river-rearing sockeye salmon were compared with estimated lengths of lake-rearing sockeye salmon. Nearly all lake-rearing sockeye salmon were from Telaquana Lake. Length of sockeye salmon at the end of the first growing season 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, at the end of the spring transition period, river-rearing sockeye salmon (105 mm) were 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).

Juvenile lengths estimated from adult salmon scales collected from the Kalskag fishwheel represent a random sample of sockeye salmon primarily rearing in the middle upper watershed and upstream, 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 & 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 during May-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 2004 (51.5°F) and relatively low during 2003 (48.6°F).

COMPARISON OF KUSKOKWIM SOCKEYE GROWTH WITH OTHER STOCKS

Kuskokwim scale growth (based on Kalskag samples) during the first year 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 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 that spawned in rivers without access to lake habitat (94% of total), indicating that scale growth of river-type sockeye in the Kuskokwim watershed (FW1: 0.41 mm;

FW1 & 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 & 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 in 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 fry was considered. However, unusually few subyearling and yearling coho salmon and no two-year old coho smolts were observed while sampling for sockeye salmon from late June through September. A few yearling coho 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 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 (Fig. 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 supports the largest population 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 (760 km). 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.

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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 (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 (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 (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 (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

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 & SWP L), and growth during spring of the smolt migration (FWPL).

Life stage	Adult year	Growth year	Location	River km	Length (mm)	SE	Count	Skewness
FW1	2005	2001	Stony R	540	117.9		1	
FW1	2005	2001	Kuskokwim R	270	110.2	6.2	2	0.00
FW1	2005	2001	Telaquana Lk	760	94.4	6.1	6	-1.04
FW1	2005	2001	Holitna (Chukowan)	710	93.2		1	
FW1	2005	2001	Hoholitna	540	90.9	3.4	7	0.01
FW1	2005	2001	Holitna	700	88.3	2.0	16	-0.82
FW1	2005	2001	Kogrukluk R	715	86.5	3.3	13	1.09
FW1	2005	2001	Aniak R	320	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	760	110.5	1.7	63	-1.04
FW1	2006	2002	Tuluksak R	222	**97.2**	1.3	78	0.25
FW1	2006	2002	Hoholitna	540	**96.5**	2.1	40	0.24
FW1	2006	2002	George R	450	**95.3**	2.6	32	0.24
FW1	2006	2002	Holitna	700	**94.6**	1.3	86	0.11
FW1	2006	2002	Kwethluk	190	**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	540	**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	320	**90.2**	1.8	37	0.53
FW1	2006	2002	Kogrukluk R	715	**89.9**	2.1	40	0.29
FW1	2006	2002	Holitna (Chukowan)	710	**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
FW1	2007	2003	Telaquana Lk	760	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	320	**88.8**	1.3	79	0.45
FW1	2007	2003	Holitna	700	**88.1**	1.4	49	-0.17
FW1	2007	2003	Hoholitna	540	**87.8**	1.6	39	0.20
FW1	2007	2003	Kuskokwim R	270	**87.4**	2.2	38	0.01
FW1	2007	2003	Holitna (Chukowan)	710	**87.3**	3.3	18	-0.09
FW1	2007	2003	Stony R	540	**87.3**	8.8	6	0.37
FW1	2007	2003	Kwethluk	190	**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	715	**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	270	127.6	11.2	2	0.00
FW1 & FWPL	2005	2002	Telaquana Lk	760	118.8	7.1	6	-0.14
FW1 & FWPL	2005	2002	Stony R	540	117.9		1	
FW1 & FWPL	2005	2002	Kogrukluk R	715	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	700	101.0	4.8	16	1.19
FW1 & FWPL	2005	2002	Aniak R	320	97.8	7.2	6	0.01
FW1 & FWPL	2005	2002	Hoholitna	540	94.5	4.0	7	-0.18
FW1 & FWPL	2005	2002	Holitna (Chukowan)	710	93.2		1	

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Table 2.2.–Page 2 of 3.

Life stage	Adult year	Growth year	Location	River km	Length (mm)	SE	Count	Skewness
FW1 & FWPL	2006	2003	Telaquana Lk	760	116.1	1.4	63	-0.41
FW1 & FWPL	2006	2003	Kwethluk	190	**100.3**	1.9	72	0.59
FW1 & FWPL	2006	2003	Hoholitna	540	**100.0**	2.5	40	0.35
FW1 & FWPL	2006	2003	Tuluksak R	222	**99.3**	1.5	78	0.54
FW1 & FWPL	2006	2003	George R	450	**99.1**	3.1	32	0.59
FW1 & FWPL	2006	2003	Kogrukluk (Shotgun)	720	**98.2**	3.6	14	0.24
FW1 & FWPL	2006	2003	Stony R	540	**98.0**	4.5	14	-0.52
FW1 & FWPL	2006	2003	Holitna	700	**96.8**	1.4	86	0.19
FW1 & FWPL	2006	2003	Kuskokwim R	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	320	**95.3**	2.4	37	0.54
FW1 & FWPL	2006	2003	Kogrukluk R	715	**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)	710	**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	540	120.9	6.0	6	0.11
FW1 & FWPL	2007	2004	Telaquana Lk	760	119.9	2.8	28	0.60
FW1 & FWPL	2007	2004	Kuskokwim R	270	119.1	2.7	38	0.06
FW1 & FWPL	2007	2004	Kogrukluk (Shotgun)	720	118.4	7.0	7	-1.04
FW1 & FWPL	2007	2004	Holitna	700	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	190	**112.5**	1.4	139	-0.46
FW1 & FWPL	2007	2004	Holitna (Chukowan)	710	111.6	3.9	18	0.51
FW1 & FWPL	2007	2004	Aniak R	320	**110.0**	2.2	79	0.05
FW1 & FWPL	2007	2004	Hoholitna	540	**109.7**	2.6	39	0.01
FW1 & FWPL	2007	2004	Kogrukluk R	715	**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	Kogrukluk R	715	29.0	5.0	13	-0.68
FWPL	2005	2002	Telaquana Lk	760	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	320	16.4	7.7	6	0.30
FWPL	2005	2002	Holitna	700	12.7	5.0	16	0.97
FWPL	2005	2002	Hoholitna	540	3.5	3.5	7	2.04
FWPL	2005	2002	Holitna (Chukowan)	710	0.0		1	
FWPL	2005	2002	Stony R	540	0.0		1	
FWPL	2006	2003	Kuskokwim R	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	540	6.9	3.7	14	1.53
FWPL	2006	2003	Kwethluk	190	6.0	1.5	72	1.87
FWPL	2006	2003	Telaquana Lk	760	5.6	1.6	63	1.89
FWPL	2006	2003	Aniak R	320	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	450	3.9	1.7	32	2.14
FWPL	2006	2003	Hoholitna	540	3.5	1.7	40	2.91
FWPL	2006	2003	Kogrukluk R	715	3.4	1.7	40	3.11
FWPL	2006	2003	Holitna	700	2.3	0.9	86	3.44
FWPL	2006	2003	Tuluksak R	222	2.1	1.1	78	4.16
FWPL	2006	2003	Holitna (Chukowan)	710	0.0	0.0	20	
FWPL	2006	2003	Holokuk/Oskawalik R	380	0.0	0.0	10	

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Table 2.2.–Page 3 of 3.

| Life stage	Adult year	Growth year	Location	River km	Length (mm)	SE	Count	Skewness
FWPL	2007	2004	Holokuk/Oskawalik R	380	**43.0**	3.2	4	0.31
FWPL	2007	2004	Stony R	540	**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	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
FWPL	2007	2004	Kwethluk	190	**27.7**	1.8	139	-0.13
FWPL	2007	2004	Holitna	700	**27.4**	3.0	49	0.01
FWPL	2007	2004	Kogrukluk R	715	**26.5**	3.3	44	0.04
FWPL	2007	2004	Holitna (Chukowan)	710	24.3	5.8	18	0.30
FWPL	2007	2004	Hoholitna	540	21.9	3.1	39	0.18
FWPL	2007	2004	Aniak R	320	21.2	2.2	79	0.24
FWPL	2007	2004	Telaquana Lk	760	14.1	3.8	28	1.11

Note: Values that were significantly different ($P < 0.05$) from the value in the box (e.g., Telaquana Lake) are highlighted in bold. Values are shown in descending order within each life stage and year.

Figure 2.1.–Map of the Kuskokwim River watershed showing major tributaries, adult salmon weirs, and the Kalskag tagging location.
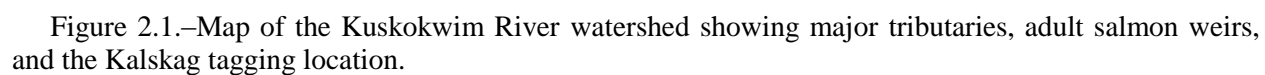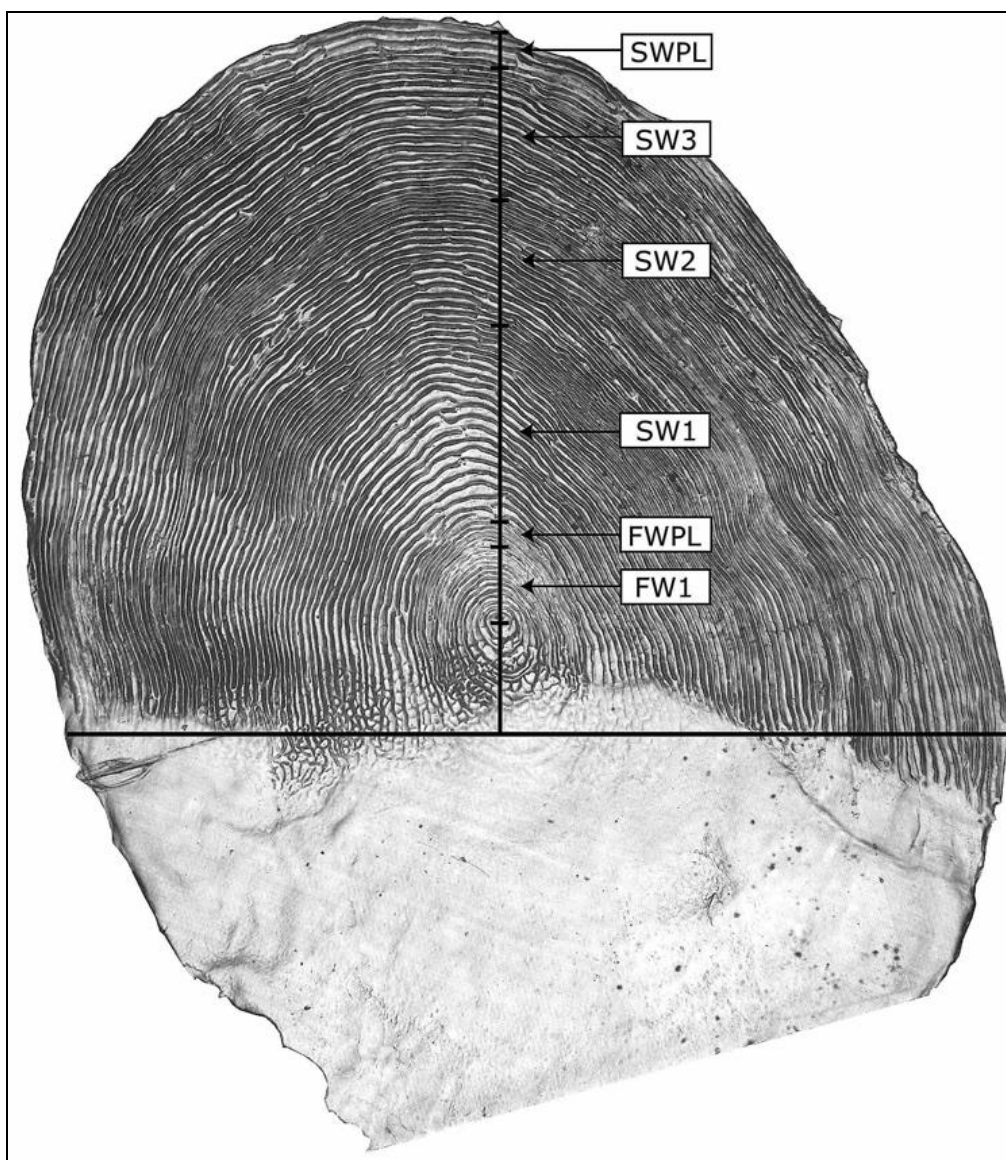
Source: Ruggerone et al. 2007

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).
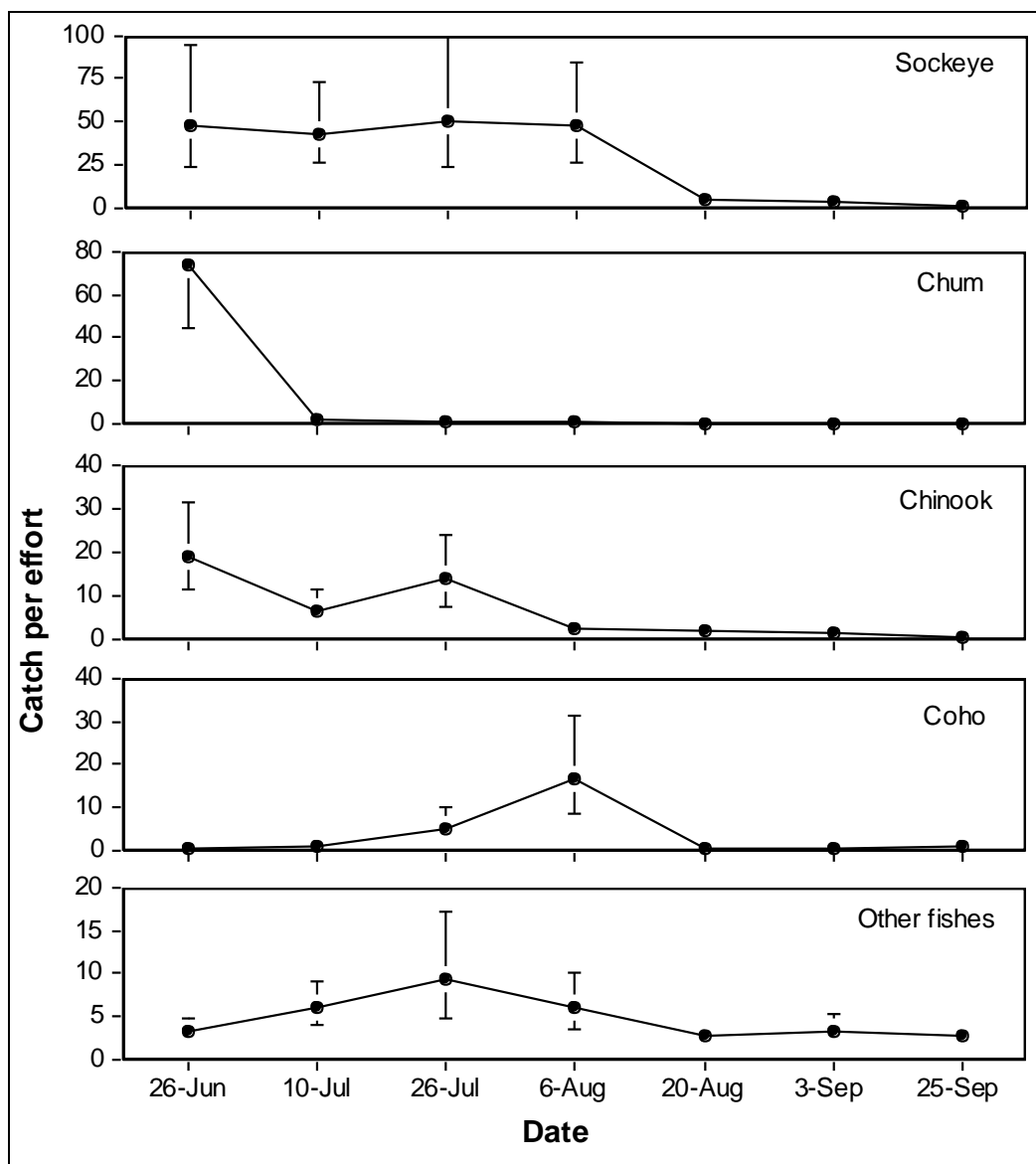
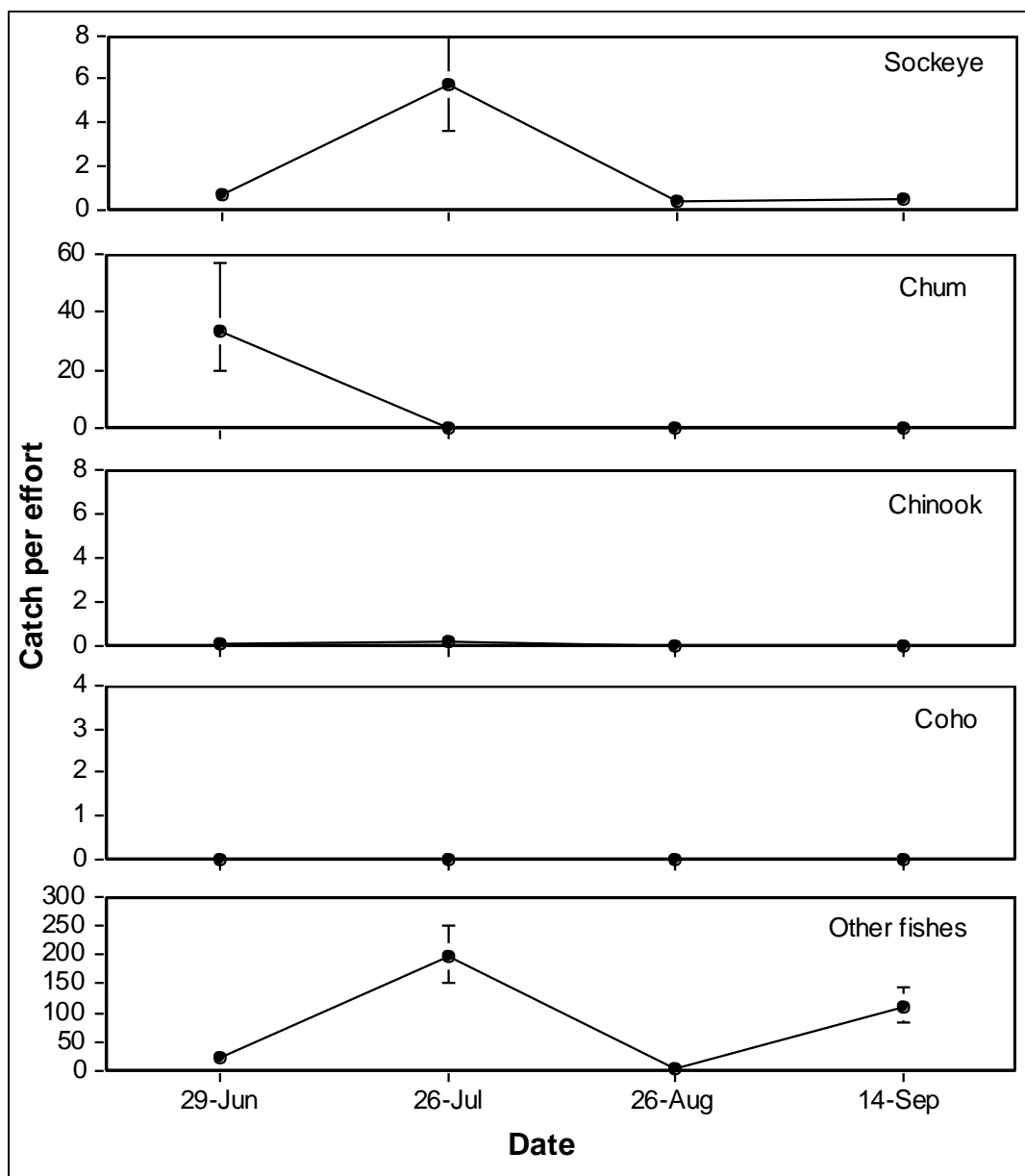*Note:* The Y-axis changes in each graph in order to highlight seasonal trends.

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.
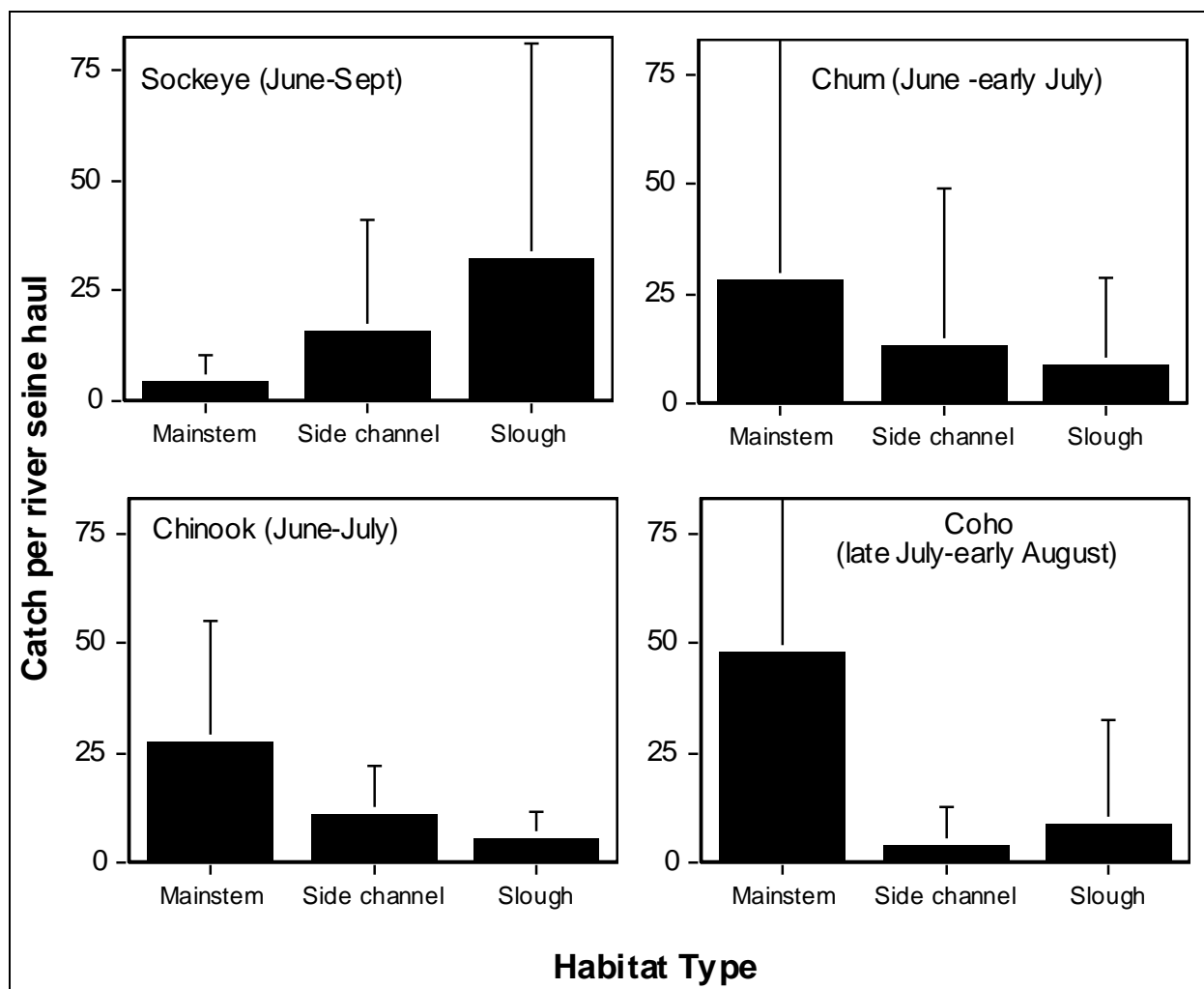
Note: Time period of data varies by species and excludes periods when few salmon were present.

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

Note: The Y-axis changes in each graph in order to highlight seasonal trends.

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.
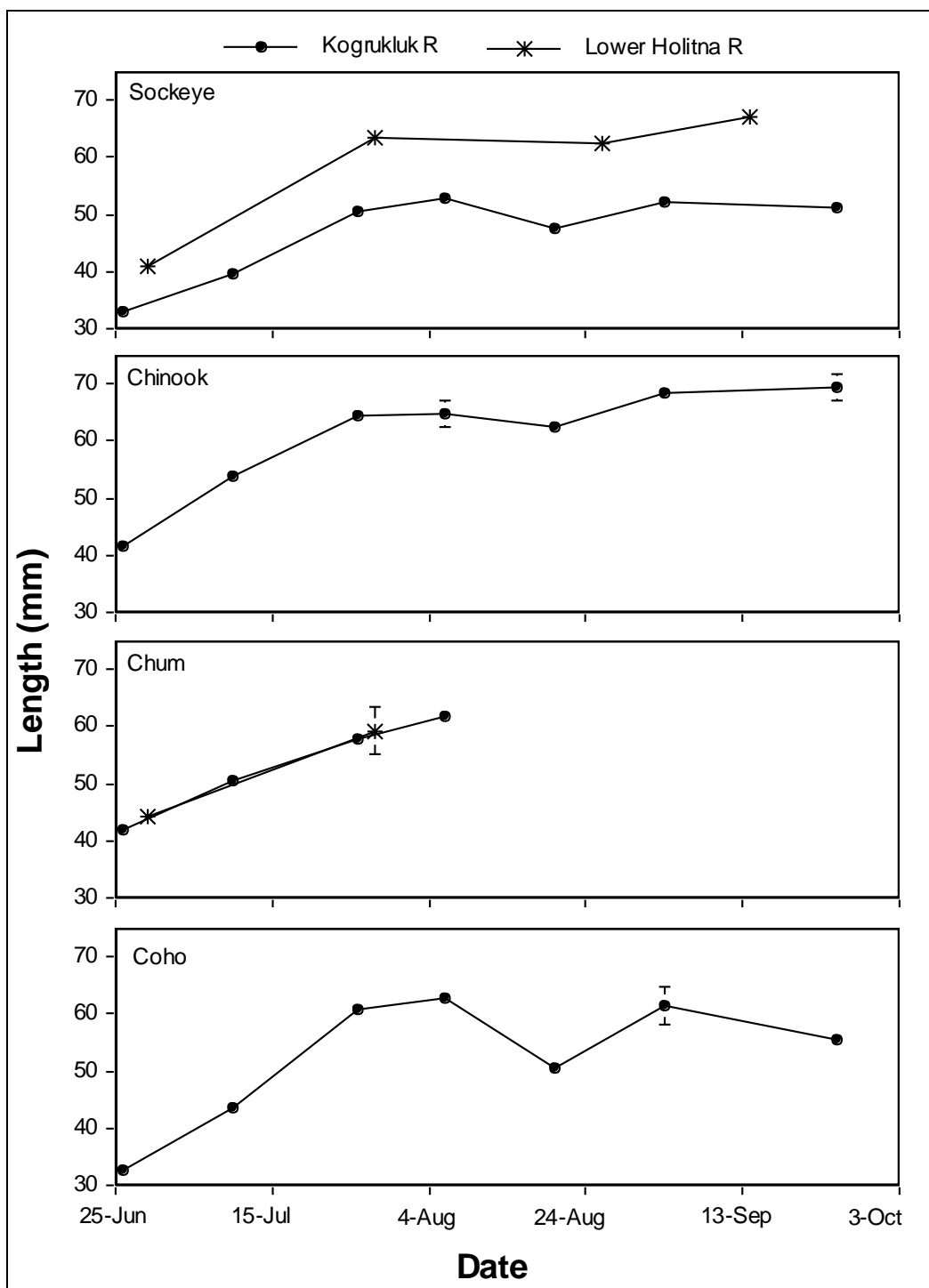
Figure 2.6.–Mean live length (± 1 SE) of age-0 salmon in the upper and lower Holitna River from late June to late September, 2006.
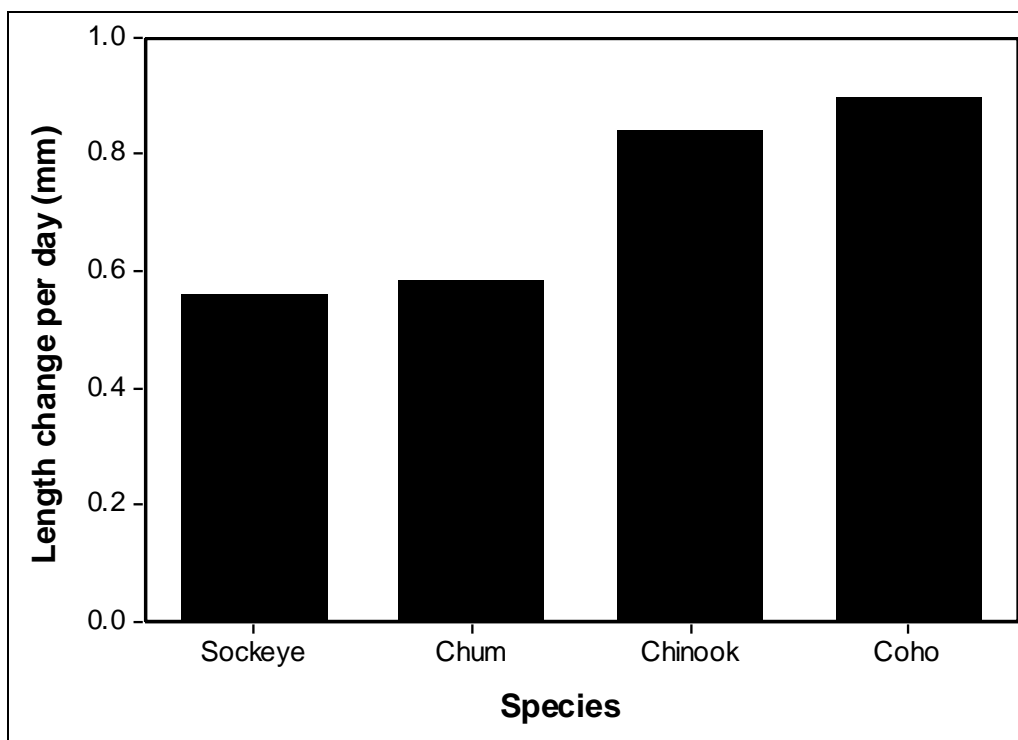
Note: Values are based on change in mean length during the period when change was relatively consistent and catch rates were relatively high. Values reflect growth and movement of individuals into and out of the study area.

Figure 2.7.–Approximate mean growth per day of juvenile salmon in the Kogrukluk River during June and July 2006.
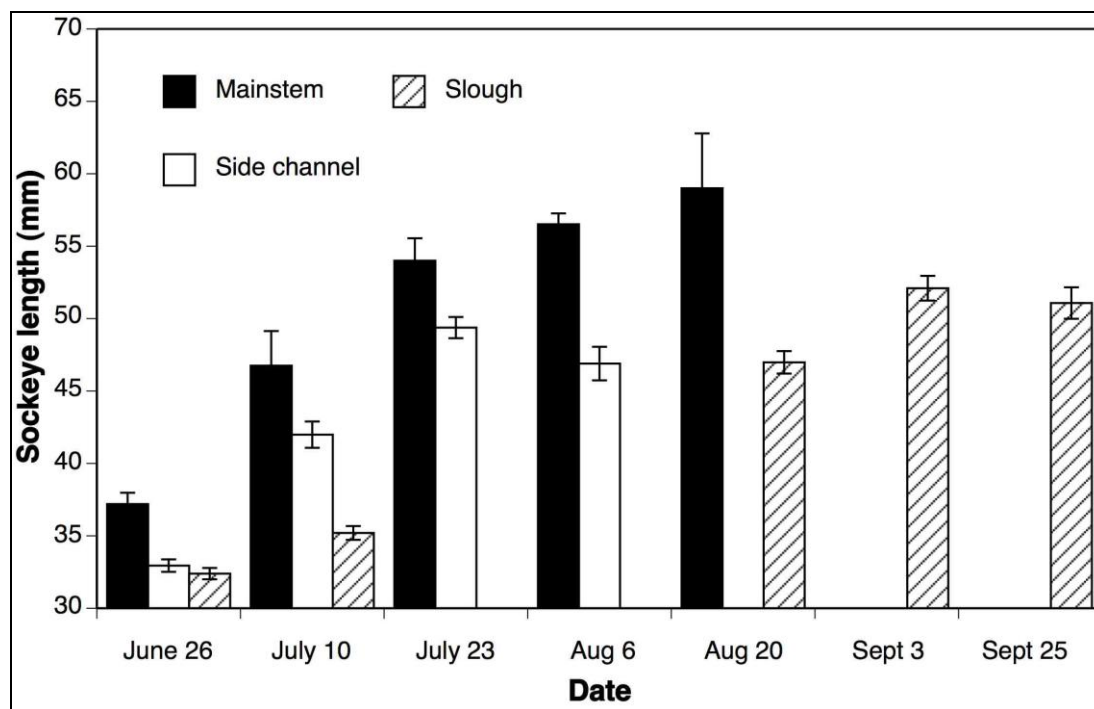
Figure 2.8.–Mean length mean (± 1 SE) of subyearling sockeye salmon captured in mainstem, side channel, and slough habitats of the Kogrukluk River during late June through September 2006.

$$Y = 27.77 + 152.51 \text{ (scale radius)}, R^2 = 0.82$$
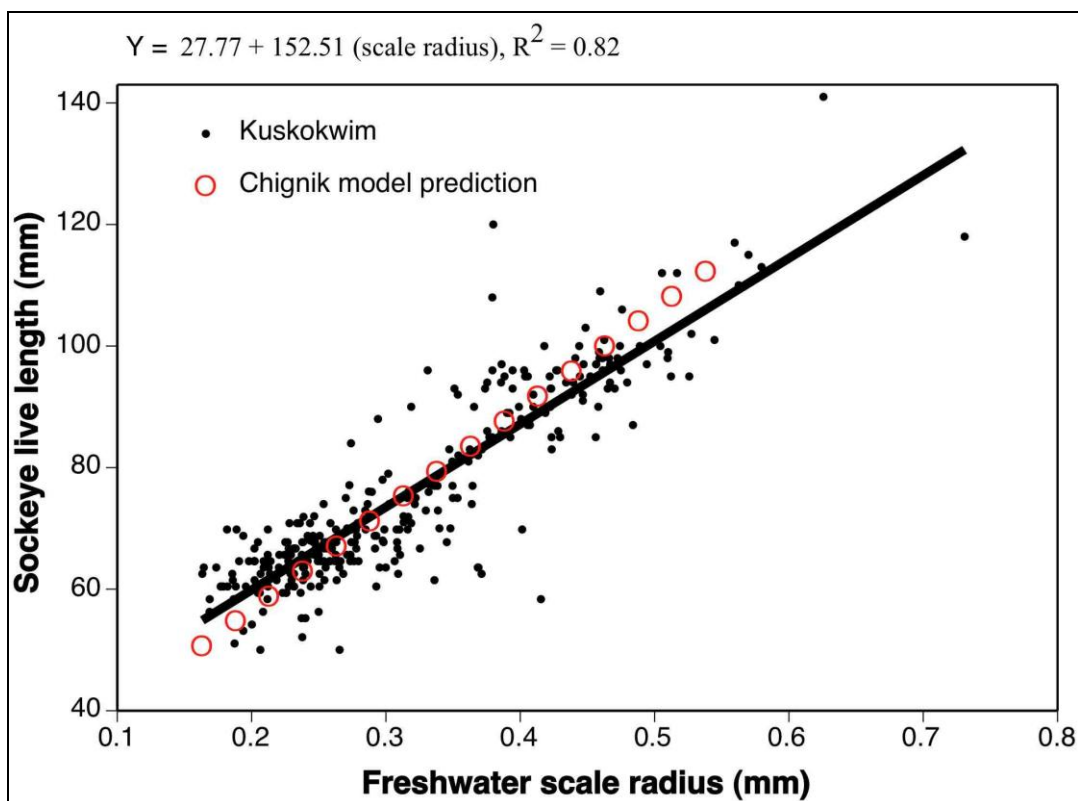
Note: The geometric mean regression for juvenile sockeye salmon from the Chignik watershed, Alaska, is shown for comparison.

Figure 2.9.–Geometric mean regression of juvenile Kuskokwim River sockeye salmon length on their freshwater scale radius (FW1 & FWPL).
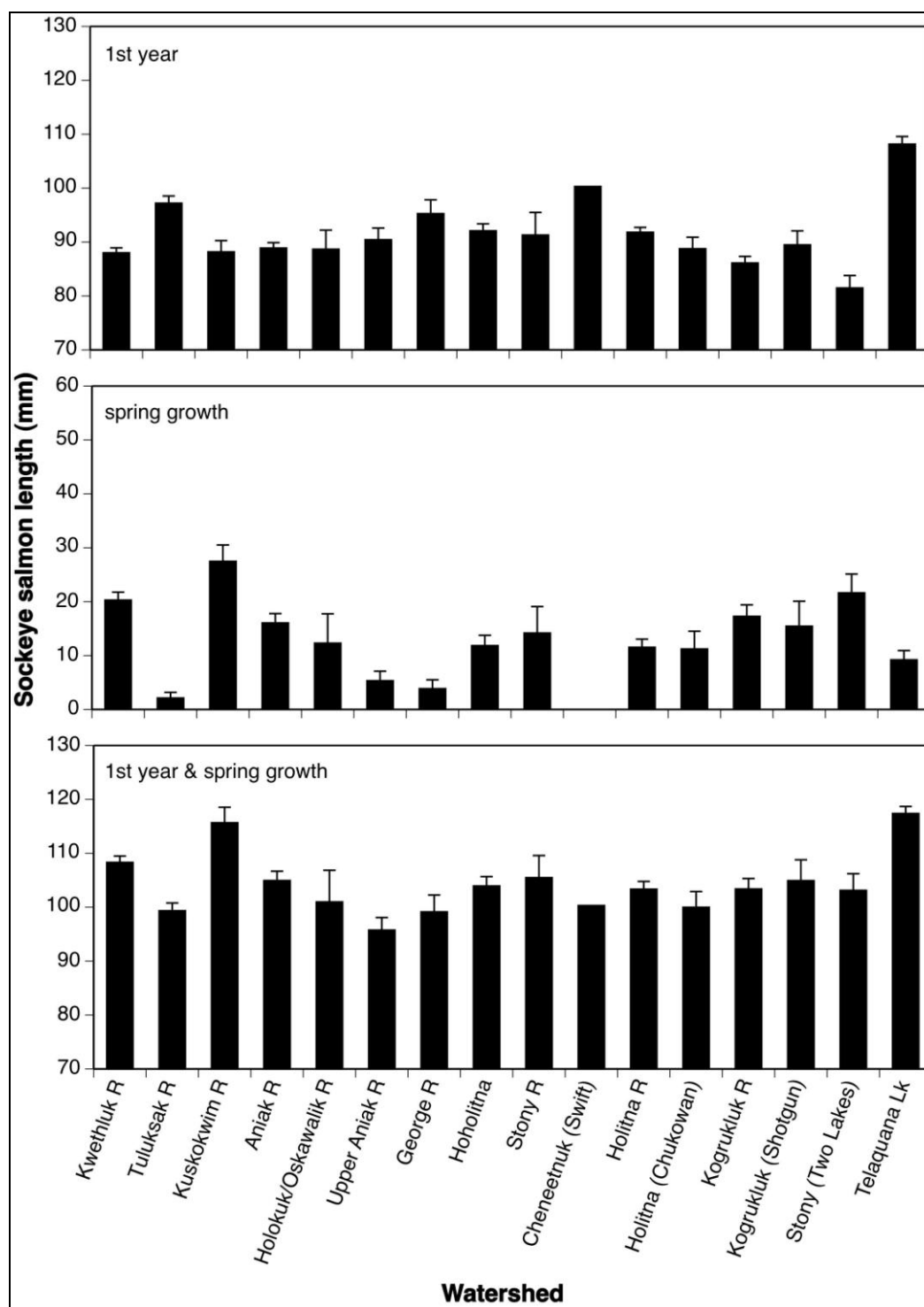
Note: Values include all data from adult return years 2005, 2006, and 2007.

Figure 2.10.–Mean (± 1 SE) estimated 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.
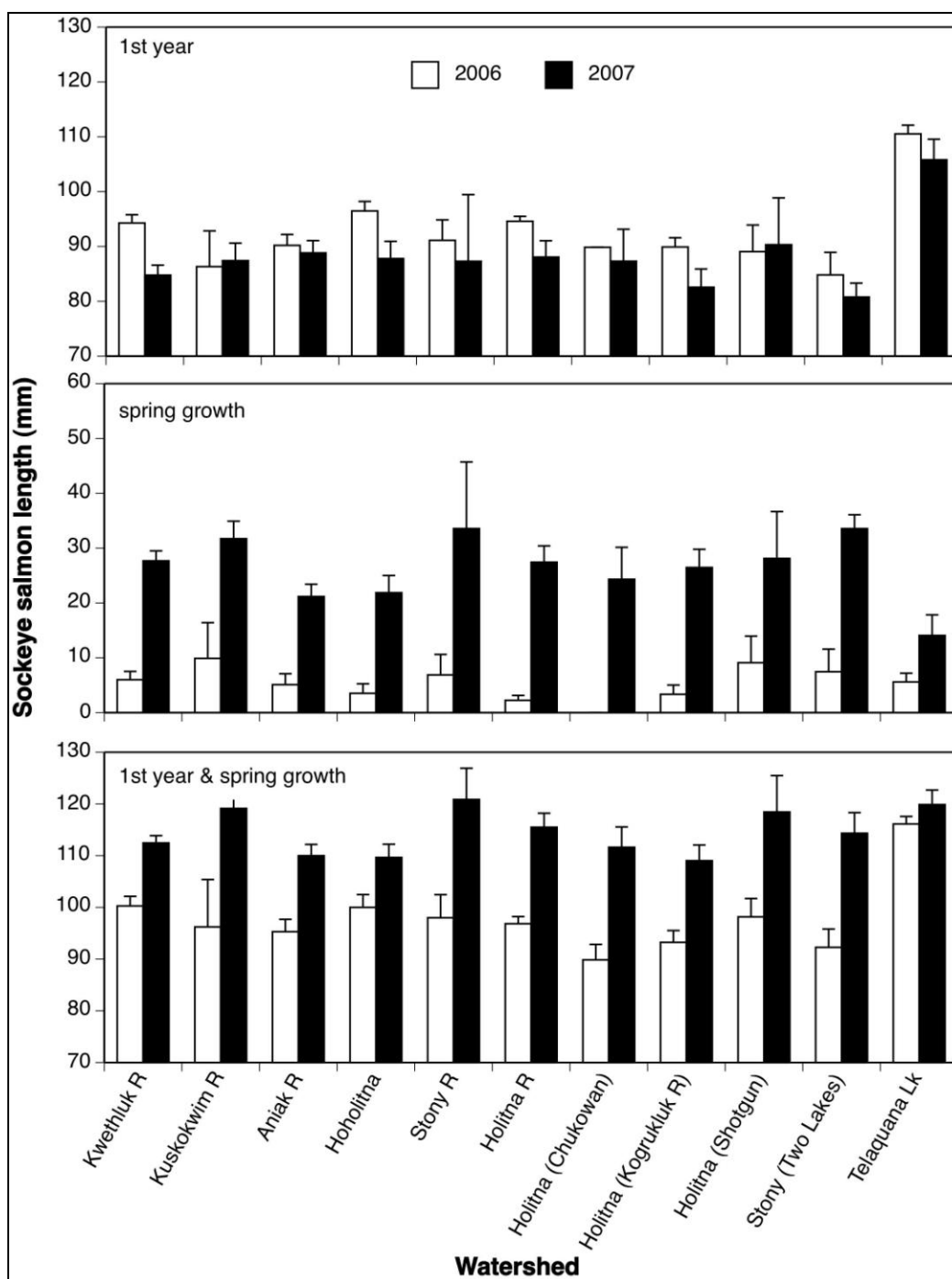
Note: Watersheds having few scales or scales during only one year were excluded.

Figure 2.11.–Comparison of mean (± 1 SE) estimated length of sockeye salmon from each area and life stage in the Kuskokwim River drainage during adult return years 2006 versus 2007.
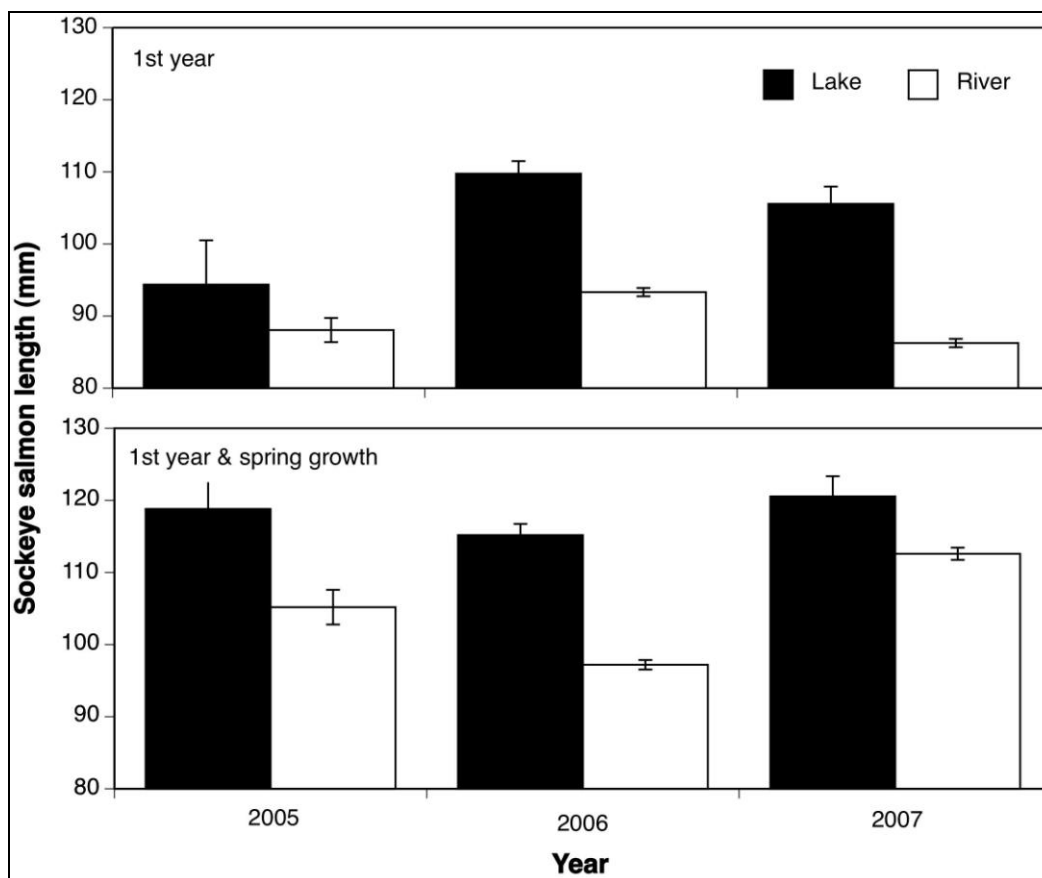
Figure 2.12.–Comparison of estimated mean length (± 1 SE) of river- versus lake-rearing sockeye salmon during each life stage, adult years 2005 – 2007.
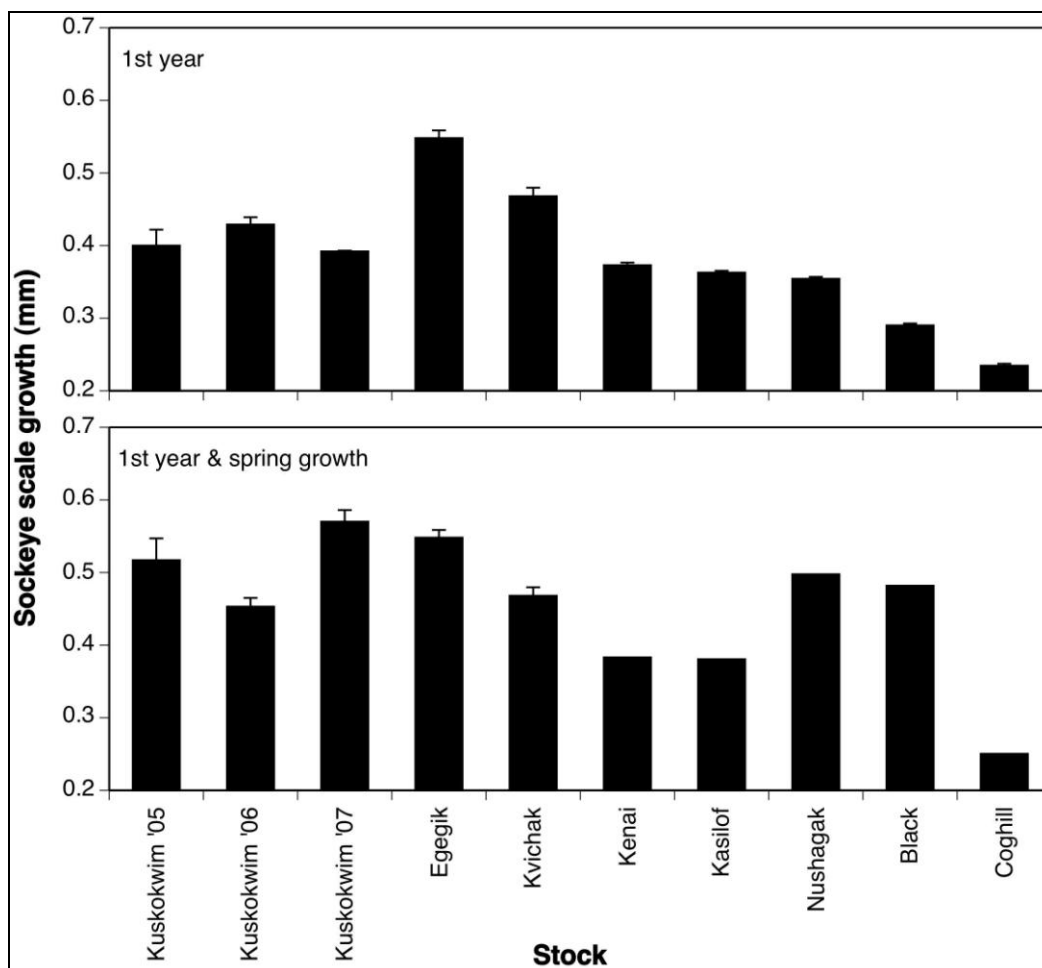
Note: Nushagak is the Nushagak District (a few sockeye river-rearing salmon).

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

Setting the river seine along the mainstem (top) and slough (bottom) of the Kogrukluk River.

Examples of slough habitat in the Kogrukluk River.

Setting the river seine in the lower Holitna River.

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 this study we developed and implemented a specific outreach and capacity building plan that was nested within several other more long-term programs. We were able to meet our immediate needs while also contributing to the long-term efforts. We communicated with the Kuskokwim River Salmon Management Working Group before, during, and after the study focusing on "two-way communication." Through this process local input was included into the study design and we were able to build working relationships with members. These efforts led to better research and more community support. We communicated with communities closest to the research activities to ensure that they were aware of the research and that their concerns had been included. We built relationships in these communities and avoided the pitfalls of community misconceptions and disapproval. We communicated with the Kuskokwim area general public about this research and applications to management using several techniques. We kept people informed and laid the foundation for future public participation. We taught lessons in village school classrooms about the basics of fisheries science and management and helped prepare and inspire students to pursue fisheries careers and to become involved citizens. We also were able to build relationships with teachers and school staff which laid the foundation for future projects. We hired several local residents in fisheries technician and intern positions and supported their professional development. In the process, biologists learned from local residents and local residents learned from biologists. We encouraged individuals to take their skills and experiences back to their communities and organizations so that their communities and organizations would also benefit by increased capacity. KNA and AVCP did specific research and outreach duties and institutionalized these responsibilities. Though they currently still have fragile fisheries programs, through this research they have built their capacities by "learning by doing" and have become stronger partners in fisheries research. Their successful programs continue to capture their leaderships' attention and the attention of other local leaders which has allowed for the programs to become more and more locally driven. The Kuskokwim Area ADF&G Commercial Fisheries Division built their capacity to do outreach and partner with Rural Alaskan Native organizations and continued to build relationships which will aid in future research and management. All these efforts were mutually supportive of one-another and were part of a multi-level, strategic approach to outreach and capacity building in the Kuskokwim area.

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

INTRODUCTION

Local involvement is essential for effective fisheries research and management in rural Alaska and can help guide management decisions as well as increase community acceptance of those decisions. In the past, local residents have often not adequately been involved in research and management which resulted in distrust of agencies and lack of acceptance of fisheries management. In one extreme case operations of the Kwethluk River weir (Kuskokwim Basin) were suspended in 1993 due to community misconceptions and resulting political action (Miller et al. 2007). However, during the past two decades there has been a strong statewide movement supported by agency leaders as well as rural Alaskan leaders for agencies and local communities and organizations to work more closely together. Often the avenues to communicate and work together do no exist or are in an incipient form. In addition, 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 this study, requested as part of the study design an outreach and capacity building plan (AYKSSI 2005). However, the concept of outreach is blurry and researchers have interpreted it to mean everything from simply informing the public to public participation in research. The AYKSSI steering committee also realized that the concept of capacity building in Alaska fisheries management is ambiguous and 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). This chapter is an attempt to explain our efforts and approach

to outreach and capacity building for this study and to relate our experience to that of others. We hope that this chapter compliments the existing literature on Alaskan fisheries outreach and capacity building and generates continued discussion and debate on these topics.

BACKGROUND

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.

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)

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)

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)

From these definitions it is clear that outreach and capacity building are related and interconnected. Outreach is essentially a foundational form of capacity building which allows for agencies and the public to create the shared understandings necessary for further capacity building (Cannon et al. 2005). Our interpretation of the distinction between the two concepts is that outreach is most about the actual communication and public involvement processes while capacity building is about the larger systemic process of change. However, these two concepts clearly can not be isolated from each other.

Outreach comes in many varieties and can include tenants of congressional, corporate, media, non-governmental organization, and government agency relations (NOAA 2006). However, for the purpose of this report we will focus on public outreach which includes public involvement, public information, public education, and informational products (NOAA 2006). 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 collect informally and as a secondary goal. Public participation outreach is focused on collecting public input, usually in a formal manner, to include into research and management. Of course, the ideal is when these two types of outreach occur at the same time and one can not distinguish between the two processes—this represents true "two-way communication." However, there is a time and place for the each of these different types of outreach depending upon project outreach objectives. In addition, focusing on delivering a particular informational message does not preclude the incorporation of two-way communication.

Outreach, in relation to fisheries research projects, is a continuous process that starts before a research project begins, takes place throughout the research project, and continues long after the research project is completed (AYKSSI 2006; NOAA 2006). Involved public and local leaders (stakeholders) need be aware of proposals and local input needs to be considered in study designs (NSF 2008; AYKSSI 2006). As the project develops, project leaders and stakeholders need to share the task of informing the greater public about the project field activities, results, and applications to management (Meffe et al. 2002). Constant communication throughout the research project is a must which will help researchers and stakeholders learn together about the specifics of the fisheries research, how the research is being received by communities, and how outreach is impacting both the communities and the research project (Ramirez and Quarry 2004; Meffe et al. 2002). Communication should continue after the research project is completed which aides in creating the foundation for future research. However, research projects and associated funding generally only last a few years which does not allow for this complete process of outreach to take place. Therefore, outreach efforts associated with particular research projects ideally are nested within long-term outreach programs and rely on past efforts as well as contribute to current and future efforts. However, if long-term outreach programs are not available that does not mean outreach should not happen but rather that the need to conduct outreach is even more pressing and researchers should focus on developing outreach eforts that could potential lead to long-term outreach programs.

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). Researchers need to be careful, thoughtful, and culturally sensitive (Cannon et al. 2005; NSF 2008) or they run the risk of being elitist and ineffective by simply attempting to change people to be more like the culture from which the professional comes. This delicate situation calls for both upward accountability (i.e. recipient to funding entity or mentor) and downward accountability (i.e. funding entity or mentor to recipient) and clear communication to ensure culturally appropriate change is happening (Land 1999). However, often accountability and communication are not clear and funding entities' and outside expectations are not met (Taylor and Clarke 2008). Recipients may not even know what the outside expectations are and often there are no clear guidelines or accepted procedures for capacity building (Cannon et al. 2005). In addition, it is difficult to connect efforts with results and little research has been attempted on this topic. 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:

- 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).

- 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.

- Integrate all levels of capacity building including the individual, organization, and the greater society and focus on encouraging transfer of capacity among these levels.

- Account for the realities of context specific factors including politics, economics, and culture.

- Incorporate a strong element of local control and initiative.

- 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.

- 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;

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) Employee Rural Alaskan residents in fisheries research;

6) Build the capacity of KNA and 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

Communications between the Kuskokwim River Salmon Management Working Group (KRSMWG) and the Kuskokwim Area ADF&G Commercial Fisheries Division lead to the development of this research project. We continued to communicate regularly with the KRSMWG throughout the formative stages of this research project, the pilot study in 2005, and the study implementation. We will continue to communicate about the study results as we plan for future research. Members' input was consider throughout the development and implementation of this project and we kept members informed of study progress by slideshow presentations during the spring and fall meetings and brief oral updates during summer meetings. The KRSMWG is an advisory group composed of representatives from commercial, sport, and subsistence user groups throughout the River that meet on a regular basis throughout the summer, once in the fall, and once in the spring (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 local residents prior to, during, and after the study as suggested by others (AYKSSI 2006;

Cannon et al. 2005; Meffe et al. 2002). 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 the closest communities to the fish wheels sockeye salmon tagging portion of the study. We described the intended field research activities to the tribal leaders of these communities using a slideshow presentation at the January, 2006 KNA Tribal Gathering in Aniak. Most residents of these communities were already familiar with the field research activities at the fish wheels because of past fish wheel salmon tagging projects (Stuby 2007, Pawluk et al. 2006).

The community of Sleetmute is the village closest to the lower Holitna River juvenile sockeye salmon project. We contacted community leaders by phone and discussed the project field research activities. 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 with residents.

Our personalized methods of one-on-one conversations with community leaders and targeted community meetings were effective and helped build relationships with local community residents. Residents appreciated these personalized efforts which were in accordance with a traditional culture that is strongly based on personal relationships. However, there may be a place for mass media or mass mailings to help prepare residents for upcoming meetings or visits and also update residents after relationships have been established by village visits. More experimentation with these methods is warranted.

COMMUNICATION WITH GENERAL PUBLIC

We wrote one news article titled, "Kuskokwim River Sockeye Salmon: Secrets Revealed" describing the study methods, relevance to management, and preliminary results. The article was published August 2006 in the Delta Discover Newspaper (Bethel, Alaska) and on the ADF&G website news series, Alaska Fish and Wildlife News. Doug Molyneaux requested and received an interview from KYUK (Bethel, Alaska public radio station) in 2006. He discussed with News Reporter, Kenny Steele study methods, relevance to sustainable fisheries management, and preliminary results.

We presented study summaries at regional meetings including meetings of the 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 15-20 minute slideshows covering several Kuskokwim fisheries projects followed by questions and answers and handouts of project summaries. Several advisory group members indicated through informal feedback that as a result of our presentations they had a more thorough understanding of this study and a better appreciation for how this study would aid fisheries management.

We worked with tribal councils and village schools to arrange community meetings in ten villages (Table 3.2). We sent meeting announcement signs to post offices, tribal councils, and

local businesses and asked them to post the signs. We also encouraged residents to attend by directly inviting them by phone or in person and by visiting the schools and requesting that the students tell their families about the meetings. We also directly invited high school students and often teachers would encourage students to attend by offering extra credit. When available by donation, we advertised and offered door prize as well. We had variable turnout from 2 to 15 people at each meeting (Table 3.2).

Meetings lasted about two hours and included handouts of project summaries and slideshow presentations with intermittent discussions. Presenters covered several Kuskokwim projects at each meeting and spent approximately 5-10 minutes on each project. We encouraged questions, discussions, and feedback and adapted the meeting to best address the topics that people desired to discuss. Meeting attendants indicated through questionnaires and informal feedback that as a result of the meetings they had a better understanding of fisheries research and a better appreciation for how research aides in fisheries management.

We used multiple methods to inform the public about our study as suggested by others (Meffe et al. 2002) and ideally, we would have applied all of our methods to all Kuskokwim residents. However, we were faced with the reality of a limited budget and so we used low cost mass media efforts and then focused on doing more personalized efforts in conjunction with existing programs (Orabutt and Thalhauser 2008; Patton 2007).

Kuskokwim area mass media news outlets are readily accessible and include one public radio station (KYUK) and two regional news papers (Delta Discovery and Tundra Drums). KYUK is the only radio station most Kuskokwim residents receive and the Delta Discovery and Tundra Drums newspapers are delivered weekly to the majority of Kuskokwim communities. Radio and newspaper reporters are often in need of stories and know that fisheries issues are very important to Kuskokwim residents, and therefore, are willing to cover fisheries management issues including research projects. Through these mass media news outlets Kuskokwim researchers were able to reach a large audience with a moderately comprehensive message for a low cost and time investment. The major drawbacks of using mass media are that it is difficult to receive feedback and build relationships; however, mass media is a good complement to other more personalized outreach methods.

By using the more personalized methods of public presentations, community meetings, and school visits, project staff were able to communicate more thoroughly, receive feedback, and build relationships and trust with residents. Building relationships and trust by face-to-face communication is often the key to communicating the sometimes complex messages of fisheries research and management and this is even more apparent in Rural Alaska. However, traveling to villages and planning meetings was expensive and time consuming and often only a few people attended meetings. Though, who attends (e.g. community leaders and elders) is often more important than how many people attend and the overall impacts of community meetings through secondary communication (meeting attendants telling others) are hard to estimate. The effectiveness of community meeting techniques in Rural Alaskan fisheries management surely varies with the specific context and is an area in need of further investigation.

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. We worked closely with school teachers to schedule and teach several lessons including fisheries careers, fish species and life cycles, fisheries research and monitoring, specific fisheries science techniques including radio telemetry, 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 12th 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.

Including K-12 classroom outreach into this research project may seem a bit excessive because it is not as common as focusing on adults (Kim and Fortner 2008). However, 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 including involvement in fisheries research and management. K-12 outreach is a great opportunity for fisheries researchers to have a large impact on and invest in long-term community capacity. Nationwide scientific researchers are becoming more involved in K-12 outreach at funding agencies' request (Kim and Fortner 2008). Scientific agencies are realizing the need for citizens to be more engaged in the scientific process to tackle the evermore complex and sometimes controversial modern issues (Leshner 2007). These same agencies are also realizing the nation-wide trend of poor K-12 student performance in core subjects and the essential need for education reform (Ernst and Monroe 2004; NRC 1999). These realizations are even more apparent in Rural Alaska where many villages lack science and math teachers, and students struggle to relate to text books and lessons that are based on life in more developed areas. Fisheries researchers in Rural Alaska have strong incentives to include K-12 outreach into research projects to help educate future scientists and encourage future community involvement.

We taught K-12 students about fisheries ecology, science, and management with a focus on the Kuskokwim area. Our goal was to help students improve their knowledge and skills and empower them to participate in fisheries research and management. Teaching lessons and giving presentations is the most common way researchers become involved in K-12 outreach and is an important activity that helps educate students and gives a scientific professional presence in the classroom (Kim and Fortner 2008). In addition, this level of involvement generally satisfies funding agencies' requirements. However, these activities are still rudimentary and will not alone lead to full understanding of and participation in fisheries management, nor will they lead to any major improvement in students' performance in core subject areas. Students need what some educators term a "literacy" in regards to fisheries management which is to posses an intimate understanding, the ability to critically think (i.e. apply knowledge to solve real world problems), and the self-confidence to participate in a social system (Spirn 2005; Freire and Macedo1987). This type of knowledge most often comes from students working on real-world problems. However, a close surrogate is for students to work in a mostly independent manor on realistic lessons that have a local setting. Fisheries researchers alone working under the constraints of the demands of a research project can not adequately facilitate this type of learning. However, this situation begs for partnerships between researchers and teachers at local schools. Researchers and teachers could work together to share data and develop lessons based

on real local fisheries research as has been requested by several teachers throughout this project (personal communication Kuspuk School District Science Curriculum Committee; personal communication Linda Cassasas, Kuspuk School District). This type of instruction can have lasting impacts on beliefs and attitudes of students, support learning in core subject areas, and carry-over to adulthood which would help meet the goals of both fisheries researchers and educators (Ernst and Monroe 2004; Lieberman and Hoody 1998).

EMPLOYMENT OF RURAL ALASKAN RESIDENTS

Hiring and training technicians and interns from rural communities has been one of the more successful capacity building efforts in Alaskan fisheries management and our most successful effort as well. We pooled funding from this project with funding from the Partners for Fisheries Monitoring Program (See Orabutt and Thalhauser 2008; and Patton 2007 for further details) to employ ten Kuskokwim area college interns to assist with field research for this study: Olin Twitchel, Desiree Ulroan, Jennifer Williams, Aaron Moses, Rainy Diehl, Shauna Hamilton, Alex Dattilo, Glen Lindsey, Amanda Goods, and Jonathan Samuelson. These interns worked directly with fisheries biologist and technicians and learned about fisheries ecology, science, and careers in the process. In addition, many of these college interns received partial scholarships from funds provided through this study matched with contributions from Coastal Villages Region Fund and Barrick Gold Corporation Donlin Creek Project (now Donlin Creek LLC).

Four interns were pursuing non-fisheries careers and took the internship to make money and learn about the fisheries field to help them in their chosen careers. Two of the four have since finished their degree (one M.S. and one B.S.) and the other two are still currently enrolled in college. Four other interns were undecided about their career path and took the internship primarily to explore fisheries as a career. Two of the four have since continued their college studies pursuing non-fisheries careers; one of the four has since discontinued attending college and pursued a non-fisheries career; and one of the four has since switch to pursuing a fisheries career. Two other interns were pursuing a fisheries career and took the internship to gain experience and knowledge. These two interns have since continued their college studies and continue to purse fisheries careers. Of the three interns who have continued in the fisheries field, two have been employed by the US Fish and Wildlife Service and one has been employed by KNA. In addition, KNA and AVCP worked closely with the Alaska Native Science and Engineering Program at University of Alaska to enroll two of these interns into that program.

The main goal of the college internship program is to encourage and help students pursue fisheries careers and we were successful in doing so. However, Kuskokwim fisheries management and research also benefit and will continue to benefit from the experience gained from the interns who choose to pursue non-fisheries careers. These interns will become teachers and local leaders in the future and will have a solid understanding and appreciation for fisheries as a result of their internships.

The KNA employed eight Kuskokwim high school students as interns to assist with the field research of this study: Charles John, Charles Vanborg, Phillip Morgan, Gena Ward, Fred Vaska, Mark Vanfleteren, Johnny John III, and Amanda Goods. The high school interns worked directly with fisheries biologist and technicians and learned about fisheries ecology, science, and careers in the process. Hiring high school interns to work for 2-4 weeks was an extension of the existing KNA high school internship program (Hildebrand and Orabutt 2006) and provided the necessary link between the one-week introductory internships and more advance college

internships and technician positions. Four out of the eight students returned in following years to work in more advanced internship or technician positions.

We employed three Kuskokwim residents as fisheries technicians to assist with field research of this study: Billy Alexie, Victor Evan, and Glen Elliot. These technicians helped complete the field research and logistical duties of this study. They also provided ADF&G staff and project leaders with a local perspective on research activities.

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 idea 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 Orabutt and Hildebrand (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 in to increased capacity of the 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 aid in transferring 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 achieve 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. The 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. There has also been a deepening sense of community among Kuskokwim fisheries employees that transcends organizational boundaries and a general more supportive work environment. These efforts have resulted in greater employee job satisfaction and an increase in employee retention and promotion. The 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 and at community and advisory group meetings, many local residents reported increased learning about and support for fisheries research and management in their communities as a result of local employment in the fisheries field. Though these employee systems are still in incipient stages,

fragile, and in need of continual improvement, this intentional change in our approach to hiring and training local fisheries employees is in an exemplary case of capacity building.

This example also 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 biologist 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

We agreed upon direct and specific responsibilities of KNA and AVCP instead of operating the cooperative project under more general terms and a general agreement to share the work load. Explicitly assigning duties has allowed for accountability and prioritizing by KNA and AVCP. To ensure success, we closely examined how the specific duties and responsibilities would be accomplished. However, we incorporated and planned for flexibility, mentoring, and mutual support (i.e. covering for each other), and ultimately focused on achieving research project goals. We attempted to incorporate the specific responsibilities into the existing fisheries programs so that the fisheries programs as whole took on the responsibility which, when it worked, represented true capacity building as a process. We were not always successful and often the responsibilities were simply completed by one of the already overworked biologists which did not represent capacity building and was rather a temporary technical fix.

The KNA, AVCP, and ADF&G staff worked closely together and communicated often to support each other's efforts to ensure that all objectives of this study 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, lead 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 (Stuby 2007; Pawluk et al. 2006).

KNA and AVCP "learned by doing" as they conducted research and outreach for this project. Their fisheries programs as well as the fisheries and administrative staff ultimately will be able to more fully participate in fisheries research and management in the future and better able to communicate about the research within their communities. Participating in the mentoring of college students and technicians furthered fisheries staff abilities to recruit and work with local residents. KNA and AVCP learned from their local employees as well 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 study. However, we realized that through fisheries studies such as this one 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 Kuskokwim Area ADF&G Commercial Fisheries Division worked closely with KNA and AVCP to meet the objectives of this study and to support the professional development of Kuskokwim residents in intern and technician positions. In addition, the Kuskokwim Area ADF&G Commercial Fisheries Division 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 the Kuskokwim Area ADF&G Commercial Fisheries Division 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 as well as the overall Alaska fisheries management 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 fairy easy efforts with potentially big learning outcomes. The National Science Foundation suggests that 5-10% of a program budget should 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) represent 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) 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 pre-season 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 and continue to work with the Alaska Native Science and Engineering Program and other university programs and staff to encourage our interns while they are away at college.

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.

10) Project leaders should forge new partnerships with local teachers and schools and created realistic, local environment-based lesson using project data and design. These efforts would amplify research contributions and aid in developing future scientist and encourage future community participation.

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Table 3.1.—Presentations about the Kuskokwim Sockeye Salmon Investigations study at regional meetings.

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 biologist, and community members
Kuskokwim River Salmon Management Working Group	Bethel (Teleconference)	Througout summer 2006	Working Group members, area biologist, 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 biologist, 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 biologist, and community members
Kuskokwim River Salmon Management Working Group	Bethel	Througout summer 2007	Working Group members, area biologist, and community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Marshall	September 5-6, 2007	Committee members, area biologist, and community members
Western Interior Regional Advisory Council Meeting	Galena	October 30-31, 2007	Committee members, area biologist, 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 biologist, and community members
Yukon-Kuskokwim Delta Regional Advisory Council Meeting	Lower Kalskag	March 20-21, 2008	Committee members, area biologist, and community members

Table 3.2.—Community outreach meetings associated with the Kuskokwim Sockeye Salmon Investigations study.

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 Meetings	Lime Village	January 16, 2007	6 peolple--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 4 children
Aniak Community Meeting	Aniak	April 17, 2008	4 people--1 council member and 3 community members

Table 3.3.—Presentations about the Kuskokwim Sockeye Salmon Investigations study at regional meetings.

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 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, and1 teacher aid
Crooked Creek Schools	Crooked Creek	December 11-12, 2006	44 people--16 K-3 grade; 12 4-6 grade; and 12 7-12 grade students, 3 teachers, and 1 teachers aid
Lime Village Schools	Lime Village	January 16, 2007	9 students 7-12, 1 teacher, and 1 teachers 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
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 high school
Quinhagak High School	Quinhagak	May 8-9, 2007	17 students, 1science teacher, and 1 principal
Kwethluk High School	Kwethluk	May 10, 2007	30 students
Nunapitchuk High School	Nunapitchuk	May 17, 2007	10 students

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School Visited	Location	Date	Estimated Number of People Attending
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 Schools	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