U.S. Fish & Wildlife Service

Run Timing, Abundance, and Distribution of Adult Coho Salmon in the Kasilof River Watershed, Alaska, 2007

Alaska Fisheries Data Series Number 2008-19

Kenai Fish and Wildlife Field Office
Kenai, Alaska
December, 2008

The Alaska Region Fisheries Program of the U.S. Fish and Wildlife Service conducts fisheries monitoring and population assessment studies throughout many areas of Alaska. Dedicated professional staff located in Anchorage, Juneau, Fairbanks and Kenai Fish and Wildlife Offices and the Anchorage Conservation Genetics Laboratory serve as the core of the Program's fisheries management study efforts. Administrative and technical support is provided by staff in the Anchorage Regional Office. Our program works closely with the Alaska Department of Fish and Game and other partners to conserve and restore Alaska's fish populations and aquatic habitats. Additional information about the Fisheries Program and work conducted by our field offices can be obtained at:

http://alaska.fws.gov/fisheries/index.htm

The Alaska Region Fisheries Program reports its study findings through two regional publication series. The **Alaska Fisheries Data Series** was established to provide timely dissemination of data to local managers and for inclusion in agency databases. The **Alaska Fisheries Technical Reports** publishes scientific findings from single and multi-year studies that have undergone more extensive peer review and statistical testing. Additionally, some study results are published in a variety of professional fisheries journals.

Alaska Fisheries Data Series Number 2008-19, December 2008
U.S. Fish and Wildlife Service

Run Timing, Abundance, and Distribution of Adult Coho Salmon in the Kasilof River Watershed, Alaska, 2007

Douglas E. Palmer[1], Kenneth S. Gates[1], and Jeffrey F. Bromaghin[2]

Abstract

Run timing, abundance, and distribution information was collected on coho salmon in the upper Kasilof River watershed during 2007 using fish weirs equipped with underwater video systems and radio telemetry. Fish weirs with video systems were installed and operated on Nikolai and Shantatalik creeks between 4 August and 16 November. Each weir and video system was installed several days prior to coho salmon entering either stream. A combined total of 1,556 coho salmon was counted past the Nikolai (*N*=837) and Shantatalik (*N*=719) creek weirs between 19 August and 15 November. Peak weekly passage occurred between 16 and 22 September for both creeks. Radio-transmitters were implanted in 109 coho salmon captured in the Kasilof River between 17 August and 15 October. About 40% (*N*=43) of the radio-tagged coho salmon selected spawning locations in the study area upstream of the Kenai National Wildlife Refuge boundary at Silver Salmon Rapids. Of those fish, 29 spawned in the upper mainstem Kasilof River and 14 selected spawning locations in tributaries of Tustumena Lake. Tustumena Lake tributary streams selected by radio-tagged fish included Shantatalik (*N*=6), Nikolai (*N*=4), and Indian (*N*=4) creeks. Other radio-tagged fish spawned outside the study area in Crooked Creek (*N*=6) and the mainstem Kasilof River downstream of the refuge boundary (*N*=4). No spawning destination could be determined for about half of the radio-tagged fish.

Introduction

The Kasilof River watershed provides spawning and rearing habitat for four species of Pacific salmon including Chinook *Onchorhynchus tshawytscha*, coho *O. kisutch*, sockeye *O. nerka*, and pink salmon *O. gorbuscha*. Sockeye salmon are targeted primarily by commercial fisheries in Cook Inlet and have been the focus of numerous research, enhancement, and assessment projects within the Kasilof River watershed for nearly 30 years (Kyle 1992; Burger et al. 1995, 1997; Finn et al. 1997; Woody et al. 2000; Shields 2006). Conversely, little research and monitoring effort has been directed toward understanding coho salmon within the watershed.

Coho salmon return to the Kasilof River beginning in late July. Returns to Crooked Creek, a lower Kasilof River tributary, were monitored by the U.S. Fish and Wildlife Service (Service) and the Alaska Department of Fish and Game (Department) using a weir between 2004 and 2006. Estimates of annual escapement during this period ranged from 2,756 to 5,703 fish (U.S. Fish and Wildlife Service and Alaska Department of Fish and Game, unpublished data). Coho salmon begin returning to Crooked Creek in early August and peak in early September. Most fish have passed the weir by early October.

Authors: [1]U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Office, 43655 Kalifornsky Beach Road, Soldotna, Alaska, 99669; [2]U.S. Fish and Wildlife Service, Fisheries and Ecological Services, 1011 E. Tudor Road, Anchorage, Alaska, 99503.

Monitoring efforts for coho salmon in the upper Kasilof River watershed have been limited to ground and aerial survey counts in Tustumena Lake tributaries by the Service during 1987 (Faurot and Jones 1990) and 2006 (Palmer and Gates 2007). Faurot and Jones (1990) observed coho salmon in only four (Pipe, Indian, Glacier, and Seepage creeks) of the eleven streams surveyed during 1987. Index counts for all streams were less than 50 fish, except for Indian Creek which had a peak count of 931 coho salmon on November 9. Ground and aerial surveys of these streams were conducted again during 2006 (Palmer and Gates 2007), with similar results. Coho salmon were found in only three streams: Glacier, Indian, and Shantatalik creeks. Peak counts occurred between October 17 and 30 and were 195, 126, and 44 coho salmon in each of these streams, respectively. Coho salmon are also known to occur in Fox and Nikolai creeks (Johnson and Weiss 2006), but were not observed in surveys conducted during 1987 and 2006. Traditional knowledge of the area does indicate that coho salmon return to Nikolai Creek earlier than other Tustumena Lake tributaries (Mike Sipes, personal communication). Coho salmon likely spawn in the mainstem Kasilof River, but this has never been documented.

Coho salmon returning to the Kasilof River watershed are harvested primarily in sport and personal use fisheries. Annual sport harvest in the Kasilof River has averaged 3,185 coho salmon between 1996 and 2003 (Howe et al. 2001a-d; Jennings et al. 2004, 2006a, 2006b; Walker et al. 2003). During the same period, estimated harvest of coho salmon in the personal use dip net fishery averaged 625 fish annually (Reimer and Sigurdsson 2004). Harvest of coho salmon in federal subsistence fisheries has been minimal to date, but will likely increase in the near future because Ninilchik residents were granted customary and traditional use for salmon, trout, Dolly Varden and other char on federal waters within the Kasilof River watershed by the Federal Subsistence Board in January 2006. New regulations were implemented during 2007 that have liberalized methods and means, seasons, and harvest limits for coho salmon and other species in federal subsistence fisheries.

The development of new federal subsistence fisheries in the Kasilof River watershed has triggered a need for more detailed information on the abundance and distribution of coho salmon. To address this need, the Service developed a project using fish weirs, underwater video, and radio telemetry to identify spawning areas and determine the abundance and run-timing of adult coho salmon in two tributaries of Tustumena Lake. Project objectives during 2007 were to (1) determine the abundance and run-timing of adult coho salmon entering Nikolai and Shantatalik creeks, (2) detect the ultimate spawning destination upstream of Silver Salmon rapids (rkm 24), via the presence of at least two tagged fish, of a population comprising 10% or more of all the coho salmon passing the capture site during each temporal stratum with probability 0.8, and (3) test the hypothesis that the distributions of spawners among temporal strata are equal. Information collected from this project will provide fisheries managers with a better understanding of coho salmon spawning in tributaries of Tustumena Lake and their distribution throughout the Kasilof River watershed.

Study Area

The Kasilof River drains a watershed of 2,150 km^2, making it the second largest watershed on the Kenai National Wildlife Refuge (Refuge). The watershed consists of mountains, glaciers, forests, and the Kenai Peninsula’s largest lake, Tustumena Lake. The Kasilof River is only 31 km long and drains Tustumena Lake, which has a surface area of 29,450 hectares, a maximum depth of 287 m, and a mean depth of 124 m. All tributary streams in the watershed which drain refuge lands enter Tustumena Lake except Crooked Creek (Figure 1).

Several species of salmon, trout, char, and whitefish use this watershed for spawning and rearing habitat (Johnson and Weiss 2006), including Chinook, coho, sockeye, and pink salmon, rainbow/steelhead trout *O. mykiss*, Dolly Varden *Salvelinus malma*, lake trout *S. namaycush*, and round whitefish *Prosopium cylindraceum*.

Nikolai Creek enters the south shore of Tustumena Lake approximately 8 km SE of the lake outlet (60° 11.43'N and 151° 0.36'W; NAD83). Its watershed is approximately 95 km^2 and falls within the Refuge boundary and a designated wilderness area (Moser 1998). Nikolai Creek has a relatively steep gradient, low sinuosity, and predominately cobble substrate.

Shantatalik Creek is a tributary on the north shore of Tustumena Lake (60°17.54'N and 150°59.12'W; NAD83), approximately 12 km NE of the lake outlet (Figure 1). The creek is approximately 7 km long and can be described as having low gradient, moderate sinuosity, and a mixture of gravel and mud substrate. Shantatalik Creek provides spawning habitat for coho and sockeye salmon (Johnson and Weiss 2006).

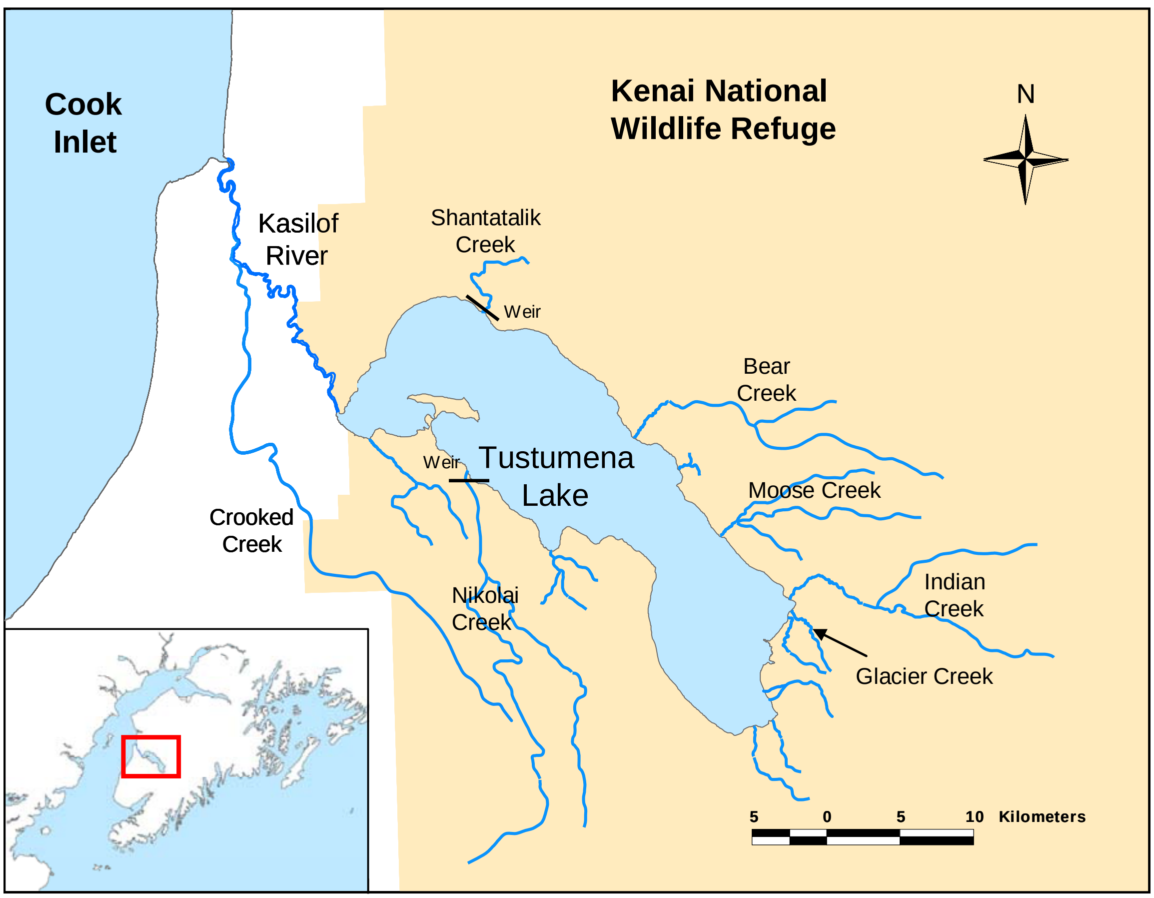

FIGURE 1.—Map of the Kasilof River watershed showing the weir locations at Nikolai and Shantatalik creeks.

Methods

Weir and Video Operations and Design

The Service operated weirs equipped with video systems to determine the abundance and run-timing of coho salmon in Nikolai and Shantatalik creeks. Both video weirs were installed on 4 August and operated through 24 October on Nikolai Creek and 16 November on Shantatalik Creek.

The Nikolai Creek weir has been operated since 2005 to enumerate steelhead trout during the spring season. The weir is approximately 200 m upstream from Tustumena Lake and is constructed using a combination of floating resistance board panels (Tobin 1994) and flexible-picket panels (Gates and Palmer 2004). The floating resistance board panels are constructed using specifications outlined by Tobin (1994), with minor changes to some materials, panel width, and resistance boards. The panels are attached to a steel rail anchored to the river bottom and are configured to pass fish near the deepest part of the channel through a fish passage panel. The flexible-picket panels are installed between the banks and bulkheads of the resistance board weir to create a fish-tight weir. The flexible-picket panels are constructed from 2.5-cm inside diameter polyvinyl chloride (PVC) electrical conduit. Panel dimensions are 3-m long by 1.5-m high with 1.9-cm spacing between pickets. Panels are held together by 3-mm stainless wire rope. The weir was unmanned, except when maintenance was required, and outfitted with a video and microwave system.

A rigid picket weir was installed on Shantatalik Creek approximately 100 m upstream from Tustumena Lake. The creek is approximately 4-m wide at the weir site. The weir framework consisted of several pieces of 6.4-mm aluminum angle bolted together forming a self-standing frame. The weir pickets were made from 25-mm schedule 40 aluminum pipe. Each picket measured 1.8-m in length and attached to the frame by individually sliding through 28.6-mm holes drilled in two 6-m pieces of aluminum angle bolted to the front of the weir frame. Weir pickets were spaced 3.2 cm apart. Like Nikolai Creek, the weir was unmanned and outfitted with a video and microwave system.

The video and microwave systems monitored fish passage in Nikolai and Shantatalik creeks. Setup and design of the video systems is described by Gates and Palmer (2006) and similar to that used by Anderson et al. (2004) on Big Creek during 2003. One underwater video camera was located inside a sealed video box attached to the fish passage chute. The video box was constructed of 3.2-mm aluminum sheeting and filled with filtered water. Safety glass was installed on the front of the video box to allow for a scratch-free, clear surface through which video images were captured. The passage chute was constructed from aluminum angle and was enclosed in plywood isolating it from exterior light. The backdrop of the passage chute from which video images were captured adjusted laterally to minimize the number of fish passing through the chute at one time. The backdrop could also be easily removed from the video chute when dirty and replaced with a new one. The video box and fish passage chute were artificially lit using a pair of 12-volt underwater pond lights. Pond lights were equipped with 10-watt bulbs to provide a quality image. The lights provided a consistent source of lighting during day and night hours. Video images from Nikolai creek weir site were transmitted via 2.4 GHz microwave frequency to a digital video recorder (DVR) located at a private residence near the Sterling Highway. A combination of 1.8 and 2.4 GHz microwave transmitters were used at Shantatalik Creek because a relay station was necessary to transmit the video images from the creek to the DVR (Figure 2). The relay station was co-located with the Nikolai Creek microwave equipment. Microwave transmission of the video signals minimizes power requirements needed at each remote site and allows the field crew to remotely monitor fish passage. A pair of 80-watt solar panels wired in parallel provided power to four 400 Ah 6-volt batteries wired in series and parallel at each weir site. These batteries and solar panels provided power to operate the underwater camera, microwave transmitter, and underwater pond lights at Shantatalik Creek and just the underwater pond lights at Nikolai Creek. One additional 80-watt solar panel and 12-volt battery powered the underwater camera and microwave equipment located on a hill near Nikolai Creek. All video images were recorded on a removable 500 gigabyte hard drive at 20 frames-per-second using a computer-based DVR. Fish passage was recorded 24 hours per day seven days each week. Stored video files were generally reviewed every two or three days. The DVR was equipped with motion detection to minimize the amount of blank video footage and review time.

Radio Telemetry

Radio telemetry was used to uniquely identify and track individual coho salmon to their respective spawning destinations. Movements of radio-tagged coho salmon were documented using a combination of fixed data-logging receiver stations located throughout the Kasilof River watershed and mobile tracking using boats and fixed-wing aircraft.

Fish Capture.—Drift gillnets were actively fished between rkm 15 and 24 to capture coho salmon for radio tagging. Methods for deploying gillnets were similar to those used to capture coho salmon for radio telemetry studies in the Holitna and Kenai rivers (Chythlook and Evenson 2003; Carlon and Evans 2007). A three person crew would deploy a single gillnet using a 5.5-m boat. One crew member piloted the boat while two crewmembers positioned on the bow of the boat tended the net. Gillnets were constructed from Miracle® (MS-30) brand twisted nylon webbing. Each gillnet fished was 12.2-m long and was 11.4-cm stretched mesh and 29 meshes deep. Drift gillnets were fished until either the end of the fishing area was reached or a fish became entangled in the net. Drift times were monitored with a stopwatch, starting when the net first entered the water and ending when all of the net was pulled from the water. Once a fish became entangled in the net, the net was immediately pulled from the water until the fish was brought on board the boat. As the net was being pulled from the water, the portion of net containing the fish was placed in a large tote filled with river water at which time the fish was disentangled or cut from the net. Once freed from the net, coho salmon were radio-tagged and placed in a submerged fish cradle for mid-eye to fork length measurements. These methods minimized stress associated with capture and handling.

Radio Tagging.—Coho salmon were radio-tagged using radio transmitters developed by Lotek Wireless Incorporated®. Radio transmitters (Model SR-M 16-25) measured 16 x 51 mm and were digitally encoded, equipped with a motion sensor, and outfitted with a 1,100-d battery which was programmed to shut off after 200 days. These radio transmitters were similar to those used by Ramstad and Woody (2003) while testing transmitter retention and tag-related mortality in adult sockeye salmon. Each transmitter weighed 17 g in air and did not exceed 2% of the fish’s body weight (Winter 1983). Radio transmitters were dispersed over four radio frequencies between 162 and 166 MHz. Radio transmitters were gastrically implanted through the esophagus using methods similar to Burger et al. (1985). Radio-tagged fish were immediately released into the river after tagging.

Radio transmitters were deployed over five strata between 12 August and 20 October (Table 1). In a coarse sense, stratum length was inversely related to the expected abundance of coho salmon. We assumed that 12 August to 20 October would encompass nearly the entire migration past Silver Salmon Rapids (rkm 24) if the migration was similar to that observed at the Crooked Creek weir, (U.S. Fish and Wildlife Service and Alaska Department of Fish and

Game, unpublished data). We assumed (1) the capture and tagging of coho salmon did not cause them to change their ultimate spawning locations, (2) fish destined for the various spawning locations had an equal probability of capture within each stratum, (3) and tagged fish behaved independently. Initially, we planned to allocate 30 radio transmitters to each of the five strata, which is the sample size required to satisfy the criteria of Objective 2 using a multinomial probability model (Agresti 2002) of spawning distribution. However, 30 transmitters could not be used because of interference on one of the radio frequencies. Loss of these 30 transmitters resulted in an allocation of 24 transmitters per stratum as outlined in Table 1.

TABLE 1.—Schedule for allocating radio transmitters in coho salmon during 2007.

Radio-tagging Strata	Radio Transmitter Allocation
12 - 31 August	24
1 - 10 September	24
11 - 20 September	24
21 - 30 September	24
1 - 20 October	24
Total	120

Radio transmitters were deployed in as short of a time period as possible within each stratum. This sampling design was similar to the "pulse sampling" typically used to sample salmon at escapement monitoring weirs (Geiger et al. 1990, Gates and Palmer 2004). This was the most efficient deployment strategy, given our limited knowledge of the abundance and run-timing of coho salmon present between river kilometer 15 and 24 from 12 August to 20 October, and our ability to capture coho salmon at this location. Tagging coho salmon as quickly as possible increased the likelihood that all tags would be deployed within each stratum. If the target number of transmitters could not be deployed within a particular stratum, we attempted to deploy the remaining transmitters in the subsequent stratum. Although pulse sampling admitted the possibility that the tagged fish were not fully representative of all fish passing during an entire stratum, any resulting bias was unlikely to be large or compromise our ability to achieve the objectives of this investigation.

Radio Tracking.—Radio telemetry receivers manufactured by Lotek Wireless Incorporated® were used for all mobile and fixed station tracking. Fixed receiver stations were used to automatically identify and record fish movements at the mouths of Nikolai, Glacier, Indian, Shantatalik and Crooked creeks, the lake outlet, Silver Salmon rapids, and between Crooked Creek and tidally influenced reaches of the Kasilof River (Figures 2 and 3). Fixed receiver stations were similar to those used on the Kenai River to monitor rainbow trout movements (Palmer 1998). Each station was comprised of a single datalogging receiver, two Yagi antennas, antenna switch box, antenna masts, 12-volt deep cycle batteries, solar panel, voltage regulator, and a strongbox. Mobile boat tracking was conducted each week from early September through late November on the Kasilof River between the lake outlet and tidewater. Aerial surveys were conducted once in September and twice each month during October and November using a PA-18 fixed-wing aircraft. Aerial surveys were conducted at approximately 300-400 m above ground on each tributary stream and along the perimeter of Tustumena Lake. A portable global positioning system (GPS) was used during all mobile tracking surveys to accurately identify the latitude and longitude of each located fish.

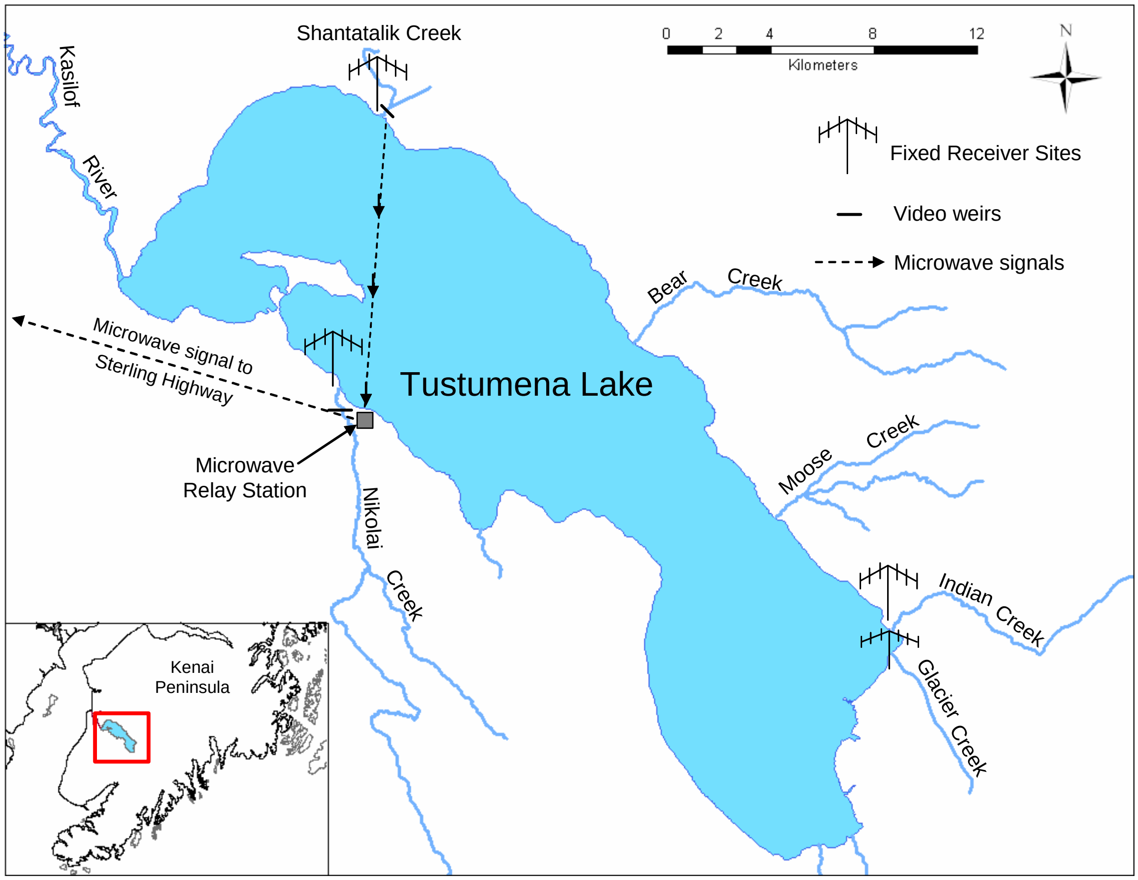

FIGURE 2.—Map of the Tustumena Lake illustrating the locations of the fixed receivers, microwave relay station and transmission routes, and video weirs, 2007.

Data Analysis

Daily counts of coho salmon passing the video weirs on Nikolai and Shantatalik creeks were entered into an Excel® database to track the abundance and run-timing on each stream. Radio telemetry information collected with various tracking methods was integrated into one database that archived the dates, locations, and fate of radio-tagged coho salmon. Locations were recorded as latitude and longitude coordinates (NAD83) and displayed on a geographic coverage of the Kasilof River watershed using ArcMap® software.

Each radio-tagged fish was assigned one of seven possible fates based on information collected from mobile and fixed radio receivers (Table 2). The collection of tagged fish known to enter the study area, any water upstream of rkm 24, constituted the sample for purposes of estimating spawning distribution from each stratum. Fish assigned a fate of harvested or dead/regurgitated were censored from the sample. Fish whose spawning location could not be determined with reasonable certainty were placed into an unknown category.

Spawning locations were defined based on the tracking results. A tagged fish that migrates to a particular location and remains in the area for an extended period of time, without activating the mortality sensor, was considered to have identified a potential spawning location. An area in which two such fish are detected was considered to be a confirmed spawning location for purposes of this investigation. Potential spawning locations are considered to be the tributaries to Tustumena Lake and the Kasilof River mainstem between the lake and rkm 24.

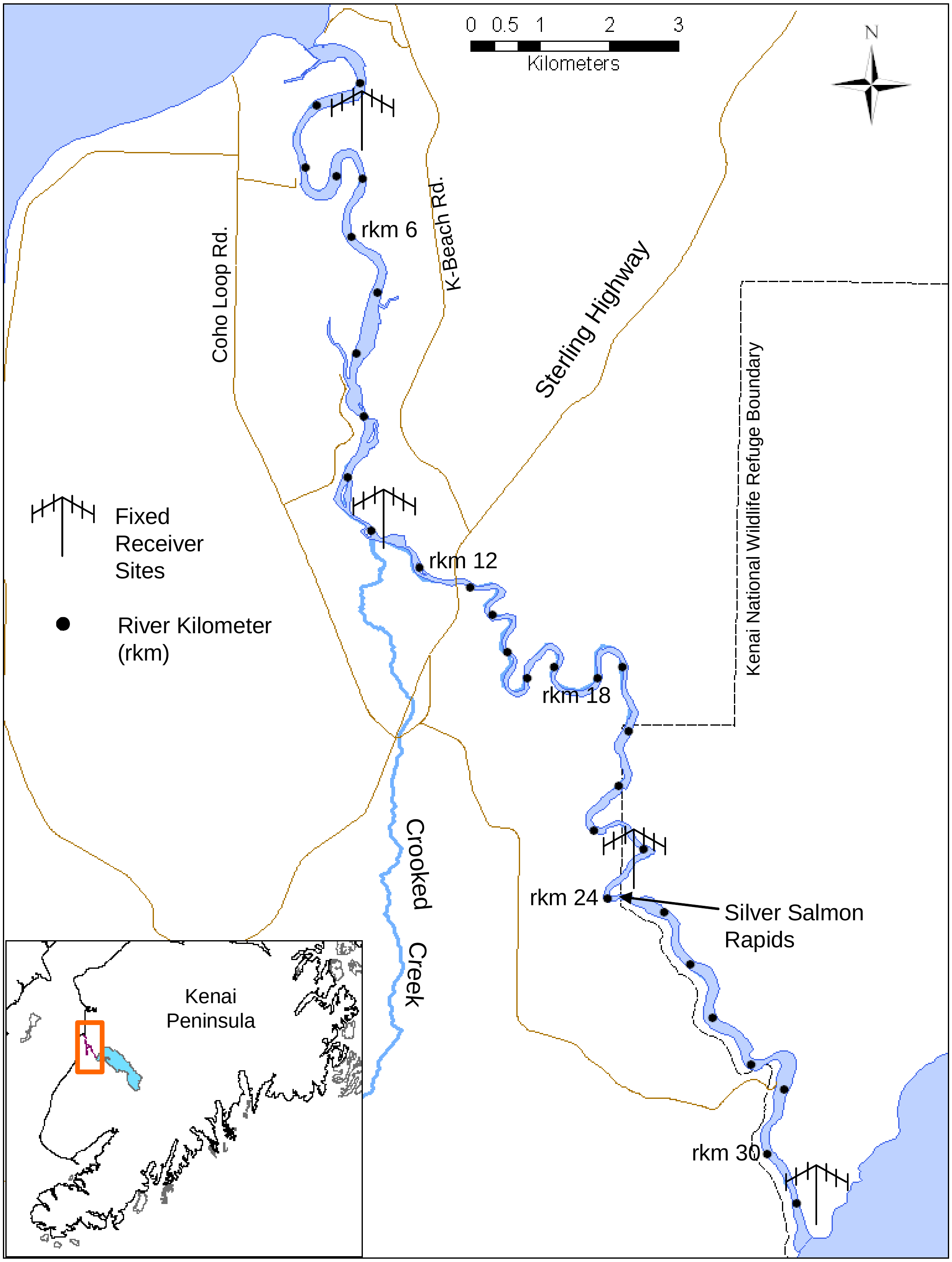

FIGURE 3.—Map of the Kasilof River illustrating the fixed receiver locations, 2007.

TABLE 2.—Possible fates of radio-tagged coho salmon in the Kasilof River watershed, 2007.

Fate	Description
Tributary Spawner	A fish that spawns in a tributary to Tustumena Lake.
Mainstem Spawner	A fish that spawns in the Kasilof River upstream of rkm 24.
Other Spawner	A fish that spawns in waters below rkm 24.
Dead/Regurgitated	A fish that did not complete its spawning migration because it has either died or regurgitated its radio transmitter.
Harvested	A fish that is harvested in either subsistence or sport fisheries.
Back Out	A fish that has dropped out of the Kasilof River watershed.
Unknown	A fish that has a loss of contact with mobile or fixed radio receivers or cannot be assigned another fate with reasonable certainty.

The hypothesis that the distribution of spawners is identical among all strata was tested using chi-square tests of homogeneity (Greenwood and Nikulin 1996). Given the relatively small stratum sample size and the potential existence of small spawning aggregations, the stratum-by-location contingency table was expected to be sparse and the distribution of the Pearson test statistic for a test of homogeneity may not be well approximated by a chi-square distribution. For that reason, an exact chi-square test (Agresti 2002) was conducted using the function "chisq.test" of R version 2.7.1 (RDCT 2008), with 100,000 replications to estimate test significance.

Results

Weir and Video Operations

The weir and video systems at Nikolai and Shantatalik creeks were installed on 4 August and operated through 24 October and 16 November, respectively. Both weirs and video systems were installed several days prior to coho salmon entering either stream. Each video system functioned well except for periodic interruptions in video signals caused by vandalism and power failures. Vandalism occurred to the Shantatalik microwave relay on 1 September and was not repaired until 4 September. Loss of video was also caused by low voltage in batteries supplying power to the microwave and video systems. The low voltage in batteries was a direct result of decreased sunlight during the fall period.

Biological Data

A total of 837 coho salmon was counted passing the video system at Nikolai Creek between 20 August and 21 October (Figure 2; Appendix 2). The total escapement estimate was adjusted down to account for 13 coho salmon that passed downstream through the video system. Peak weekly passage (N=292) occurred between 16 and 22 September with the median cumulative passage occurring on 19 September. The highest daily count (N=217) also occurred on 19 September. The number of coho salmon counted after 6 October only represented 5% (N=40) of the total escapement.

Sex composition of coho salmon returning to Nikolai Creek was determined during the review of video records and was comprised of 50% females. Sex ratios were nearly equal throughout the entire run (Figure 3). Sex could not be determined for three coho salmon; these fish were omitted from the estimate.

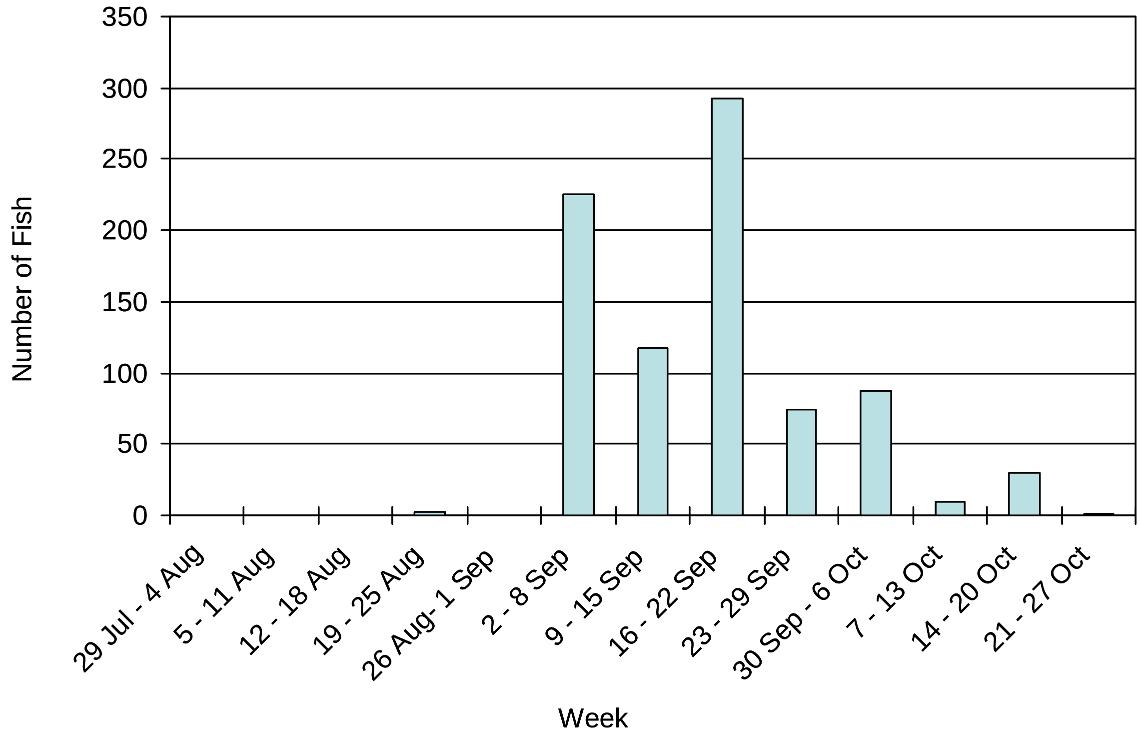

FIGURE 2. —Weekly escapement of coho salmon in Nikolai Creek, Alaska, 2007. Counts were between 4 August and 24 October.

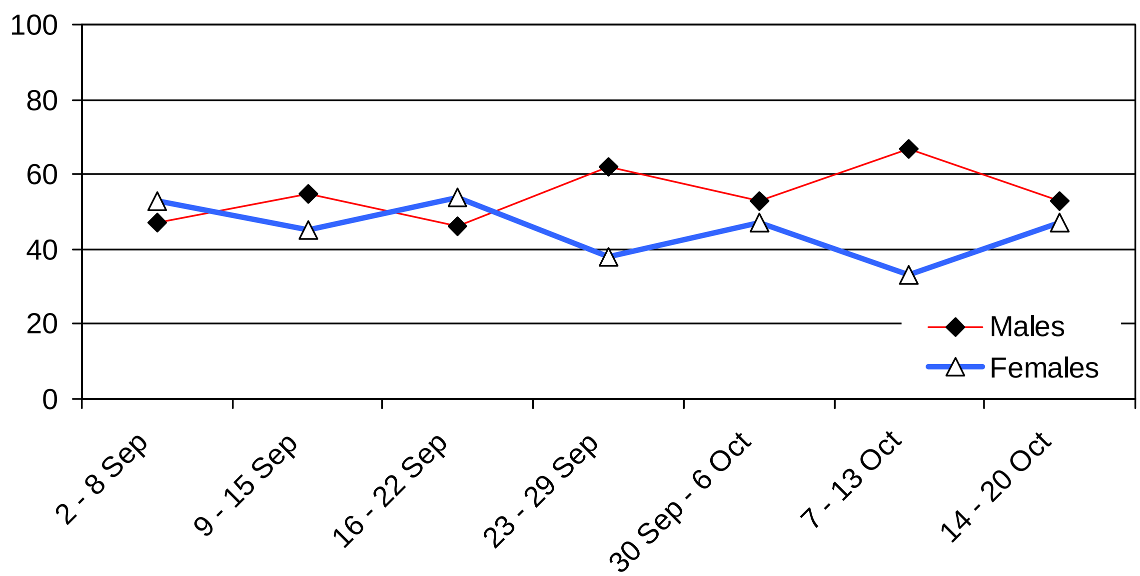

FIGURE 3. —Weekly percent of male and female coho salmon observed at Nikolai Creek, Alaska, 2007. The first five weeks and the last week of operation was omitted from this figure because of zero or low (*N*<5) passage.

A total of 719 coho salmon was counted passing Shantatalik Creek weir between 19 August and 15 November 2007 (Figure 4; Appendix 3). The total escapement estimate was adjusted down to account for 155 coho salmon that passed downstream through the video system.

Peak weekly passage (*N*=295) occurred between 16 and 22 September with the median cumulative passage occurring on 19 September. Females comprised 38% of the total escapement based on review of the video records. Sex composition was skewed towards males for most of the run (Figure 5).

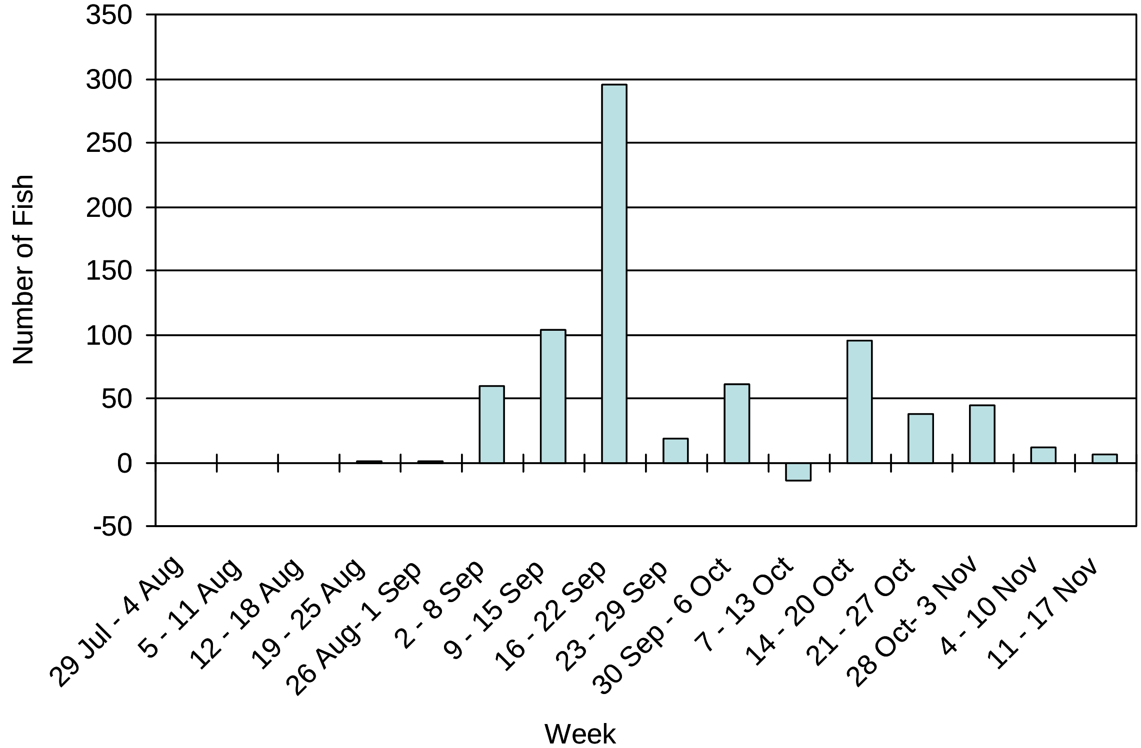

FIGURE 4. —Weekly escapement of coho salmon in Shantatalik Creek, Alaska, 2007. Counts were between 4 August and 16 November.

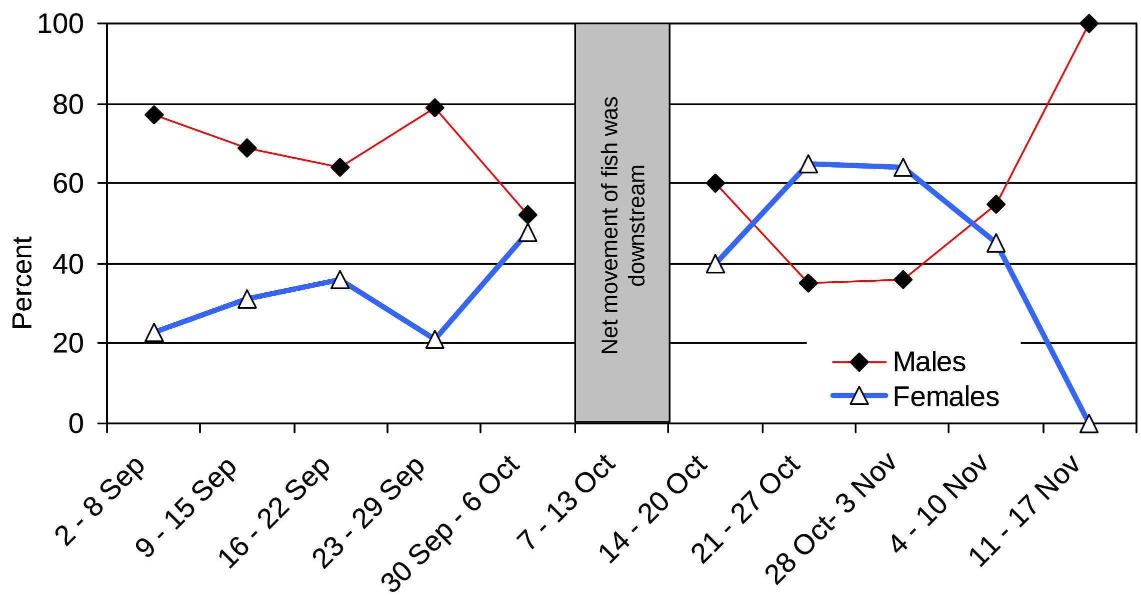

FIGURE 5. —Weekly percent of male and female coho salmon observed at Shantatalik Creek, Alaska, 2007. The first five weeks of operations were omitted from this figure because of zero or low (*N*<5) passage.

Radio Telemetry

A total of 109 coho salmon were radio-tagged in the Kasilof River between 17 August and 15 October 2007 (Appendix 4). All radio-tagged fish were captured in an 8.3-km section of river immediately downstream from the refuge boundary at Silver Salmon Rapids. Radio-tagged fish ranged from 490-685 mm in length and were comprised of 56 females and 53 males. We were successful implanting at least 24 radio transmitters in each of the five temporal strata except strata one and four. We initially implanted 24 radio transmitters during stratum one, but one of these transmitters was found on the river bank in early September and redeployed on a fish during stratum two. Only 8 radio transmitters were implanted during stratum four because of the low abundance of coho salmon in the tagging area during this time period. Five additional transmitters were implanted during stratum five.

Coho salmon radio-tagged during each of the five temporal strata were assigned one of six possible fates based on information collected from mobile and fixed radio receivers (Table 3). Nearly 40% (*N*=43) of the radio-tagged fish selected spawning locations upstream of the refuge boundary at Silver Salmon Rapids. Of those fish, 29 spawned in the upper mainstem Kasilof River between rkm 24 and the Tustumena Lake boat ramp (Figure 6). Fourteen radio-tagged coho salmon spawned in tributaries of Tustumena Lake including Shantatalik (*N*=6), Nikolai (*N*=4), and Indian (*N*=4) creeks. Other radio-tagged fish spawned outside the study area in Crooked Creek (*N*=6) and the mainstem Kasilof River downstream of the refuge boundary (*N*=4). No spawning destination could be determined for about half of the radio-tagged fish. These fish were assigned fates of “Dead/Regurgitated” (*N*=17), “Back Out” (*N*=24), and “Unknown” (*N*=15). One coho salmon assigned a “Back Out” fate migrated out of the Kasilof River and was later harvested by an angler on the Kenai River. All but one of the radio-tagged fish that were classified as “Unknown” entered Tustumena Lake but no spawning destination could be assigned.

TABLE 3. —Assigned fates of coho salmon radio-tagged in the Kasilof River between 17 August and 15 October 2007.

	Strata						
Fate	1	2	3	4	5	Total	%
Tributary Spawner							
Shantatalik Creek	5	0	1	0	0	6	5.5%
Nikolai Creek	3	1	0	0	0	4	3.7%
Indian Creek	2	0	2	0	0	4	3.7%
Mainstem Spawner (Refuge)	2	6	5	2	14	29	26.6%
Other Spawner							
Mainstem Below Refuge	0	1	0	1	2	4	3.7%
Crooked Creek	1	2	1	1	1	6	5.5%
Dead/Regurgitated	1	1	4	2	9	17	15.6%
Back Out	2	10	9	2	1	24	22.0%
Unknown	7	4	2	0	2	15	13.8%

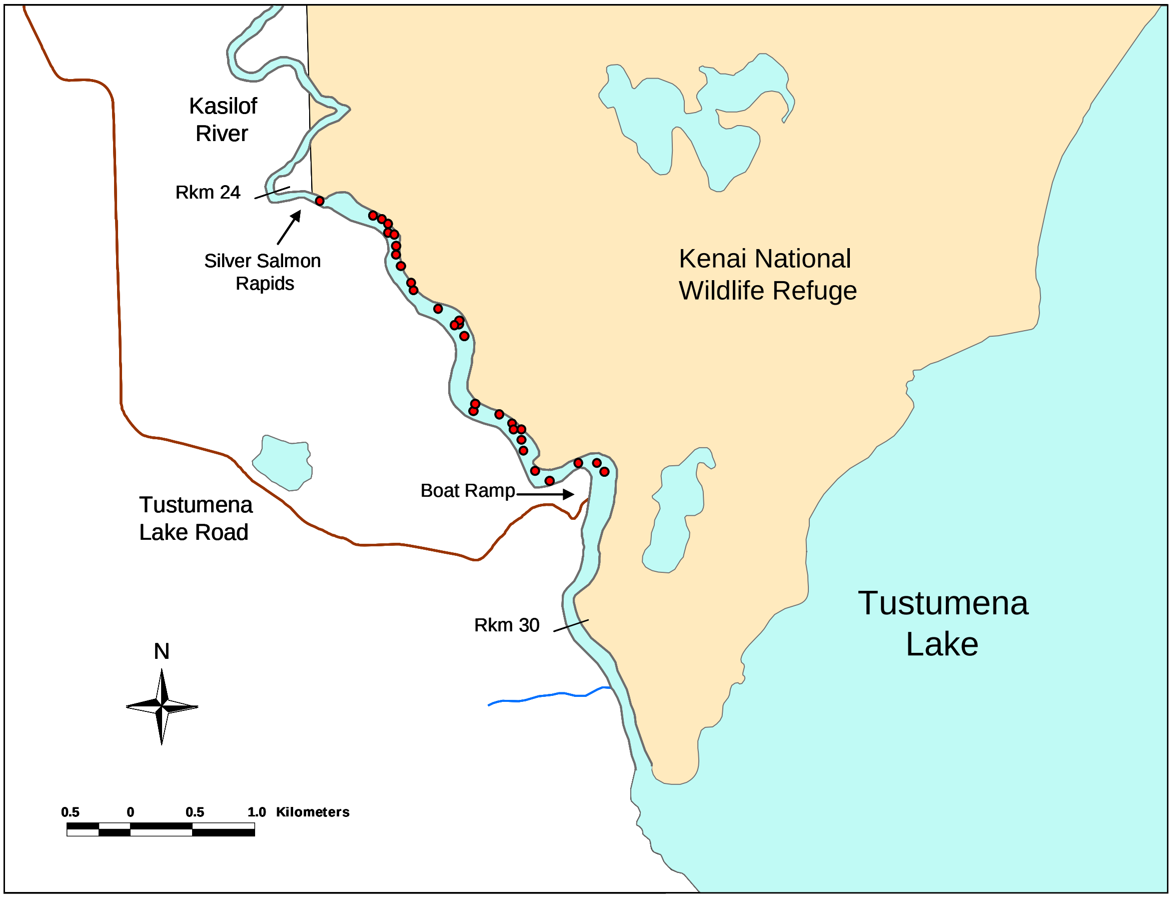

FIGURE 6. —Spawning locations selected by radio-tagged coho salmon in the upper Kasilof River during 2007.

An exact chi-square procedure was used to test the hypothesis that the distributions of spawners were equal among all five temporal strata. Spawners were classified into three categories for this test, tributary spawners (*N*=14), mainstem refuge spawners (*N*=29), and other spawners (*N*=10). The test was significant ($\chi 2$ = 29.2745, df = 8, p-value = 0.0003), indicating that the distributions of spawners were not equal among all strata. The significance of the test was primarily driven by changes in the relative abundance of tributary and mainstem spawners between stratum 1 and stratum 5 (Table 3).

Discussion

A combined total of 1,556 coho salmon was counted past the Nikolai (*N*=837) and Shantatalik (*N*=719) creek weirs between 19 August and 15 November. We feel that these estimates of abundance accurately represent the relative strength of the coho salmon return on each of these streams; however, estimates from each creek may be conservative because of periodic interruptions of video images. Periodic interruptions in video signals were caused by vandalism and power failures which resulted in 6 days of lost video at Nikolai Creek and 8 days of lost video at Shantatalik Creek (Appendices 2 and 3). The majority (71%) of video coverage was lost prior to coho salmon entering these streams which reduced any influence these interruptions had on total counts.

Spawning destinations were assigned to about half (*N*=53) of the 109 coho salmon that were radio-tagged during 2007. Forty-three of these fish selected spawning locations within the study area upstream of the refuge boundary at Silver Salmon Rapids including the mainstem Kasilof River (*N*=29) and three tributaries of Tustumena Lake (*N*=14). These findings support previous suspicions that the upper mainstem Kasilof River is an important spawning area for coho salmon. The three tributary streams of Tustumena Lake selected by radio-tagged coho salmon were Nikolai (*N*=4), Indian (*N*=4), and Shantatalik (*N*=6) creeks. These findings are consistent with the Department's Anadromous Water's Catalog (Johnson and Weiss 2006) and with ground and aerial survey counts of coho salmon conducted on Tustumena Lake tributaries by the Service in 1987 (Faurot and Jones 1990) and 2006 (Palmer and Gates 2007).

We did observe significant differences in run-timing between mainstem and tributary spawners. Although mainstem spawners were represented in all temporal strata, nearly half of these fish were radio-tagged in strata 5. Conversely, the majority of tributary spawners were radio-tagged in strata 1 indicating that tributary spawners enter the Kasilof River earlier than mainstem spawners. Differences in run-timing between tributary and mainstem spawners are common in *Onchorhychus* spp., especially in streams where timing of upstream migration extends over a period of several weeks (Groot and Margolis 1991)

No spawning destination could be determined for about half (*N*=56) of the radio-tagged coho salmon. Fates assigned to the majority (*N*=41) of these fish were either "Dead/Regurgitated" (*N*=17) or "Back Out" (*N*=24). Coho salmon assigned to these fates represented about 37% of all radio-tagged fish. Much of this 37% "failure" rate was probably due to handling-induced mortality; however, one radio-tagged coho salmon migrated out of the Kasilof River and was later harvested by an angler on the Kenai River suggesting that some "Back-Out" fish are migrating to other spawning destinations. High rates of handling-induced mortality have been observed by other researchers that have captured and handled adult coho salmon during their transition from marine to freshwater habitats. For example, Carlon and Evans (2007) observed "failure" rates as high as 40% for coho salmon radio-tagged in the Kenai River. Radio-tagged coho salmon assigned a fate of "Unknown" (*N*=15) comprised the balance of fish for which no spawning destination could be determined. Fourteen of these fish entered Tustumena Lake but never selected a spawning tributary. The ultimate fates of these fish are unclear but may be related to altered behavior or delayed mortality associated with handling. Another possibility is that some coho salmon spawned in Tustumena Lake. We did observe a localized group of these "Unknown" fish on the southern shoreline of Tustumena Lake approximately 4 km east of the Tustumena Lake outlet; however, we were not able to confirm if these fish were actually spawning and are not aware of any studies that have documented lake spawning in coho salmon.

Our radio telemetry findings in 2007 revealed that the upper Kasilof River was an important spawning area for coho salmon. The investigation plan developed for continuation of this work in 2008 (FIS 08-502) did not account for this spawning group; therefore, Objective 1 will be expanded in 2008 to also determine the abundance and run-timing of coho salmon spawning in the upper Kasilof River drainage upstream of river kilometer 24. Expansion of this objective will require modification of the methods originally outlined in the investigation plan. The new approach will use escapement counts obtained from video weirs on Nikolai and Shantatalik creeks and radio telemetry to estimate the abundance of coho salmon returning to Tustumena Lake tributaries and the upper Kasilof River. We will not operate video weirs on Indian and Glacier creeks as originally proposed but will instead expand the radio telemetry component of the study. A total of 240 radio transmitters will be deployed to track individual coho salmon to their respective spawning destinations upstream of river kilometer 24. Radio transmitters will be deployed over four strata between 16 August and 15 October. The distribution of transmitters among spawning locations and the abundance of coho salmon in Nikolai and Shantatalik creeks will be jointly used to estimate the abundance of each component population using a maximum likelihood estimator specially developed for this purpose.

Acknowledgements

Special appreciation is extended to those who participated in project setup, data collection, and video review including Waylon Marler, Chad Whaley, Todd Anderson, and Adam Reimer. We also thank Michael and Linda Sipes for providing us access to their property to operate the microwave equipment and DVR for Nikolai and Shantatalik creeks.

The U.S. Fish and Wildlife Service, Office of Subsistence Management provided funds for this project through the Fisheries Resource Monitoring Program, Project FIS 07-507.

References

Agresti, A. 2002. Categorical data analysis, 2nd edition. John Wiley & Sons, Hoboken, New Jersey.

Anderson, J. L., K. S. Whitton, K. K. Cornum, and T. D. Auth. 2004. Abundance and run timing of adult Pacific salmon in Big Creek, Becharof National Wildlife Refuge, 2003. U. S. Fish and Wildlife Service, King Salmon Fish and Wildlife Field Office, Alaska Fisheries Data Series Report Number 2004-7, King Salmon, Alaska.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of Chinook salmon *Oncorhynchus tshawytscha* in the Kenai River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 42: 693-700.

Burger, C. V., J. E. Finn, and L. Holland-Bartels. 1995. Pattern of shoreline spawning by sockeye salmon in a glacially turbid lake: Evidence for subpopulation differentiation. Transactions of the American Fisheries Society 124:1–15.

Burger, C. V., W. J. Spearman, and M. A. Cronin. 1997. Genetic differentiation of sockeye salmon subpopulations from a geologically young Alaskan lake system. Transactions of the American Fisheries Society 126:926–938.

Carlon, J. A., and D. Evans. 2007. Abundance of adult coho salmon in the Kenai River, Alaska, 1999-2003. Alaska Department of Fish and Game, Fishery Data Series Number 07-81, Anchorage, Alaska.

Chythlook, J. S., and M. J. Evenson. 2003. Assessment of Chinook, chum, and coho salmon escapements in the Holitna River drainage using radio telemetry, 2002. Alaska Department of Fish and Game, Fishery Data Series Number 03-23, Anchorage, Alaska.

Faurot, D., and R. N. Jones. 1990. Run timing and spawning distribution of coho and late run Chinook salmon in the Kasilof River watershed, Alaska, 1987. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 9, Kenai, Alaska.

Finn, J. E., C. V. Burger, and L. Holland-Bartels. 1997. Discrimination among populations of sockeye salmon fry with fourier analysis of otolith banding patterns formed during incubation. Transactions of the American Fisheries Society 126:559–578.

Gates, K. S., and D. E. Palmer. 2004. Estimation of the sockeye salmon escapement into McLees Lake, Unalaska Island, Alaska, 2003. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2004-1, Kenai, Alaska.

Gates, K. S., and D. E. Palmer. 2006. Abundance and run timing of adult steelhead trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2006. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2006-13, Kenai, Alaska.

Geiger, J. H., J. E. Clark, B. Cross, and S. McPherson. 1990. Report from the work group on sampling. Pages 3-12 in H. J. Geiger and R. L. Wilbur, editors. Proceedings of the 1990 Alaska stock separation workshop. Alaska Department of Fish and Game, Division of Commercial Fisheries, Special Fisheries Report Number 2, Juneau, Alaska.

Greenwood, P. E., and M. S. Nikulin. 1996. A guide to chi-square testing. John Wiley & Sons, New York, New York.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. University of British Columbia Press, Vancouver, British Columbia.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage, Alaska.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition: Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage, Alaska.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition: Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage, Alaska.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-8, Anchorage, Alaska.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series Number 04-11, Anchorage, Alaska.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006a. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series Number 06-34, Anchorage, Alaska.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006b. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series Number 06-44, Anchorage, Alaska.

Johnson, J., and E. Weiss. 2006. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, Effective September 15, 2006. Alaska Department of Fish and Game, Special Publication Number 06-16, Anchorage, Alaska.

Kyle, G. B. 1992. Summary of sockeye salmon (*Oncorhynchus nerka*) investigations in Tustumena Lake, 1981-1991. Alaska Department of Fish and Game, Fisheries Rehabilitation and Enhancement Division, Report 122, Juneau, Alaska.

Moser, E. 1998. Water resource inventory and assessment, Kenai National Wildlife Refuge, 1997 stream discharge gaging data. U.S. Fish and Wildlife Service, Water Resource Branch, WRB 98-01, Anchorage, Alaska.

Palmer, D. E. 1998. Migratory behavior and seasonal distribution of radio-tagged rainbow trout in the Kenai River, Alaska. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 46, Kenai, Alaska.

Palmer, D. E., and K. S. Gates. 2007. Coho salmon spawning assessment in Tustumena Lake tributaries, 2006. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Data Series Report Number 2007-10, Kenai, Alaska.

Ramstad, K. M., and C. A. Woody. 2003. Radio tag retention and tag-related mortality among adult sockeye salmon. North American Journal of Fisheries Management 23:978-982.

RDCT (R Development Core Team) 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Reimer, A. M., and D. Sigurdsson. 2004. Upper Cook Inlet personal use salmon fisheries, 1996-2003. Alaska Department of Fish and Game, Fishery Data Series Number 04-31, Anchorage, Alaska.

Shields, P. 2006. Upper Cook Inlet commercial fisheries annual management report, 2005. Alaska Department of Fish and Game, Fishery Management Report Number 06-42, Anchorage, Alaska.

Tobin, J. H. 1994. Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers. U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, Alaska Fisheries Technical Report Number 22, Kenai, Alaska.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series Number 03-05, Anchorage, Alaska.

Winter, J. D. 1983. Underwater biotelemetry. Pages 371 – 395 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Woody, C. A., J. Olsen, J. Reynolds, and P. Bentzen. 2000. Temporal variation in phenotypic and genotypic traits in two sockeye salmon populations, Tustumena Lake, Alaska. Transactions of the American Fisheries Society 129:1031-1043.

APPENDIX 1. —List of video and microwave equipment used to monitor coho salmon abundance at Nikolai and Shantatalik creeks, Alaska, 2007.

Item	Model #	Manufacturer	Contact
Digital Video Recorder	DVSM 4-120	Veltek International, Inc.	http://www.veltekcctv.com/
Underwater Camera	Model 10	Applied Micro Video	http://www.appliedmicrovideo.com/
Underwater Lights	Lunaqua 2 12-v	OASE	http://www.pondusa.com
External Harddrive	One Touch 500 GB	Maxtor.com	http://www.maxstore.com
2.4 GHz Microwave Transmitter	BE-530T	Premier Wireless, Inc	http://www.premierwirelessinc.com
1.8 GHz Microwave Transmitter	BE-700T	Premier Wireless, Inc	http://www.premierwirelessinc.com
2.4 GHz Microwave Receiver	BE-322R	Premier Wireless, Inc	http://www.premierwirelessinc.com
1.8 GHz Microwave Receiver	BE-700R	Premier Wireless, Inc	http://www.premierwirelessinc.com
2.4 GHz Parabolic Antennas	130135	California Amplifier	http://www.calamp.com
1.8 GHz Parabolic Antennas	AB10227	California Amplifier	http://www.calamp.com
80 W Solar Module	NE-80EJEA	Sharp	http://solar.sharpusa.com
400 Ah 6 Volt Battery	S-530	Rolls	http://www.rollsbattery.com/
100 Ah 12 Volt Battery	ES27	Exide Technologies	http://www.exide.com/
Charge Controller	ASC8-12	Specialty Concepts, Inc.	http://www.specialtyconcepts.com/
Charge Controller	ASC16-12	Specialty Concepts, Inc.	http://www.specialtyconcepts.com/

APPENDIX 2. —Daily counts and cumulative proportion of coho salmon from Nikolai Creek during 2007. Boxed areas represent the second and third quartile and median passage dates. Shaded areas represent complete days with no video signal because of vandalism and power outages.

	Male	Female	Unknown Sex	Downstream Male	Downstream Female	Daily Total	Daily Cumulative	Cumulative Proportion
8/4	0	0	0	0	0	0	0	0.0000
8/5	0	0	0	0	0	0	0	0.0000
8/6	0	0	0	0	0	0	0	0.0000
8/7	0	0	0	0	0	0	0	0.0000
8/8	0	0	0	0	0	0	0	0.0000
8/9	0	0	0	0	0	0	0	0.0000
8/10	0	0	0	0	0	0	0	0.0000
8/11	0	0	0	0	0	0	0	0.0000
8/12	0	0	0	0	0	0	0	0.0000
8/13	0	0	0	0	0	0	0	0.0000
8/14	0	0	0	0	0	0	0	0.0000
8/15	0	0	0	0	0	0	0	0.0000
8/16	0	0	0	0	0	0	0	0.0000
8/17	0	0	0	0	0	0	0	0.0000
8/18	0	0	0	0	0	0	0	0.0000
8/19	0	0	0	0	0	0	0	0.0000
8/20	1	1	0	0	0	2	2	0.0024
8/21	0	0	0	0	0	0	2	0.0024
8/22	0	0	0	0	0	0	2	0.0024
8/23	0	0	0	0	0	0	2	0.0024
8/24	0	0	0	0	0	0	2	0.0024
8/25	0	0	0	0	0	0	2	0.0024
8/26	0	0	0	0	0	0	2	0.0024
8/27	0	0	0	0	0	0	2	0.0024
8/28	0	0	0	0	0	0	2	0.0024
8/29	0	0	0	0	0	0	2	0.0024
8/30	0	0	0	0	0	0	2	0.0024
8/31	0	0	0	0	0	0	2	0.0024
9/1	0	0	0	0	0	0	2	0.0024
9/2	0	0	0	0	0	0	2	0.0024
9/3	0	0	0	0	0	0	2	0.0024
9/4	0	0	0	0	0	0	2	0.0024
9/5	0	0	0	0	0	0	2	0.0024
9/6	24	42	1	0	0	67	69	0.0824
9/7	24	16	0	0	0	40	109	0.1302
9/8	57	61	0	0	0	118	227	0.2712
9/9	25	21	1	0	0	47	274	0.3274
9/10	0	0	0	0	0	0	274	0.3274
9/11	0	1	0	0	0	1	275	0.3286
9/12	1	0	0	0	0	1	276	0.3297
9/13	34	24	0	0	0	58	334	0.3990
9/14	6	4	0	0	0	10	344	0.4110
9/15	0	2	0	-2	0	0	344	0.4110

–continued–

APPENDIX 2. —(Page 2 of 2)

	Male	Female	Unknown Sex	Downstream Male	Downstream Female	Total	Daily Cumulative	Cumulative Proportion
9/16	0	0	0	-1	0	-1	343	0.4098
9/17	0	0	0	-1	0	-1	342	0.4086
9/18	3	1	0	0	-1	3	345	0.4122
9/19	113	104	0	0	0	217	562	0.6714
9/20	21	54	0	0	0	75	637	0.7611
9/21	0	0	0	0	-1	-1	636	0.7599
9/22	0	0	0	0	0	0	636	0.7599
9/23	0	0	0	0	0	0	636	0.7599
9/24	3	5	0	0	0	8	644	0.7694
9/25	6	1	0	0	0	7	651	0.7778
9/26	4	5	0	0	0	9	660	0.7885
9/27	0	1	1	0	-2	0	660	0.7885
9/28	17	13	0	-1	0	29	689	0.8232
9/29	16	5	0	0	0	21	710	0.8483
9/30	0	1	0	0	0	1	711	0.8495
10/1	2	0	0	0	0	2	713	0.8519
10/2	0	0	0	0	0	0	713	0.8519
10/3	1	1	0	0	0	2	715	0.8542
10/4	15	14	0	0	0	29	744	0.8889
10/5	11	12	0	0	-1	22	766	0.9152
10/6	17	14	0	0	0	31	797	0.9522
10/7	1	0	0	0	0	1	798	0.9534
10/8	0	0	0	0	0	0	798	0.9534
10/9	0	0	0	0	0	0	798	0.9534
10/10	0	0	0	0	0	0	798	0.9534
10/11	0	0	0	0	0	0	798	0.9534
10/12	0	0	0	-1	0	-1	797	0.9522
10/13	6	3	0	0	0	9	806	0.9630
10/14	2	3	0	0	0	5	811	0.9689
10/15	1	1	0	0	0	2	813	0.9713
10/16	3	2	0	0	-1	4	817	0.9761
10/17	7	8	0	0	0	15	832	0.9940
10/18	2	2	0	0	0	4	836	0.9988
10/19	1	0	0	0	-1	0	836	0.9988
10/20	0	0	0	0	0	0	836	0.9988
10/21	1	0	0	0	0	1	837	1.0000
10/22	0	0	0	0	0	0	837	1.0000
10/23	0	0	0	0	0	0	837	1.0000
10/24	0	0	0	0	0	0	837	1.0000

APPENDIX 3. —Daily counts and cumulative proportion of coho salmon from Shantatalik Creek during 2007. Boxed areas represent the second and third quartile and median passage dates. Shaded areas represent complete days with no video signal because of vandalism and power outages.

	Male	Female	Downstream Male	Downstream Female	Daily Total	Daily Cumulative	Cumulative Proportion
8/4	0	0	0	0	0	0	0.0000
8/5	0	0	0	0	0	0	0.0000
8/6	0	0	0	0	0	0	0.0000
8/7	0	0	0	0	0	0	0.0000
8/8	0	0	0	0	0	0	0.0000
8/9	0	0	0	0	0	0	0.0000
8/10	0	0	0	0	0	0	0.0000
8/11	0	0	0	0	0	0	0.0000
8/12	0	0	0	0	0	0	0.0000
8/13	0	0	0	0	0	0	0.0000
8/14	0	0	0	0	0	0	0.0000
8/15	0	0	0	0	0	0	0.0000
8/16	0	0	0	0	0	0	0.0000
8/17	0	0	0	0	0	0	0.0000
8/18	0	0	0	0	0	0	0.0000
8/19	0	1	0	0	1	1	0.0014
8/20	0	0	0	0	0	1	0.0014
8/21	0	0	0	0	0	1	0.0014
8/22	0	0	0	0	0	1	0.0014
8/23	0	0	0	0	0	1	0.0014
8/24	0	0	0	0	0	1	0.0014
8/25	0	0	0	0	0	1	0.0014
8/26	0	0	0	0	0	1	0.0014
8/27	1	0	0	0	1	2	0.0028
8/28	0	0	0	0	0	2	0.0028
8/29	0	0	0	0	0	2	0.0028
8/30	0	0	0	0	0	2	0.0028
8/31	0	0	0	0	0	2	0.0028
9/1	0	0	0	0	0	2	0.0028
9/2	0	0	0	0	0	2	0.0028
9/3	0	0	0	0	0	2	0.0028
9/4	0	0	0	0	0	2	0.0028
9/5	0	0	0	0	0	2	0.0028
9/6	0	0	0	0	0	2	0.0028
9/7	2	1	0	0	3	5	0.0070
9/8	44	13	0	0	57	62	0.0862
9/9	7	3	0	0	10	72	0.1001
9/10	0	0	-1	-1	-2	70	0.0974
9/11	2	4	0	0	6	76	0.1057
9/12	43	19	0	0	62	138	0.1919
9/13	26	13	-2	-2	35	173	0.2406
9/14	2	0	0	0	2	175	0.2434
9/15	2	0	-8	-4	-10	165	0.2295
9/16	0	0	0	-2	-2	163	0.2267
9/17	0	0	-1	0	-1	162	0.2253
9/18	8	3	0	0	11	173	0.2406
9/19	117	73	0	0	190	363	0.5049
9/20	61	33	0	-1	93	456	0.6342
9/21	5	2	-1	-2	4	460	0.6398
9/22	0	0	0	0	0	460	0.6398
9/23	0	0	-6	-3	-9	451	0.6273
9/24	1	0	-1	-1	-1	450	0.6259
9/25	27	7	-2	0	32	482	0.6704

–continued–

APPENDIX 3. —(Page 2 of 2)

	Male	Female	Downstream Male	Downstream Female	Daily Total	Daily Cumulative	Cumulative Proportion
9/26	3	1	-5	0	-1	481	0.6690
9/27	0	0	-1	0	-1	480	0.6676
9/28	1	1	0	0	2	482	0.6704
9/29	3	1	-5	-2	-3	479	0.6662
9/30	1	0	0	0	1	480	0.6676
10/1	7	1	-1	0	7	487	0.6773
10/2	7	4	-1	0	10	497	0.6912
10/3	3	1	-2	0	2	499	0.6940
10/4	1	1	-4	0	-2	497	0.6912
10/5	7	2	-1	0	8	505	0.7024
10/6	16	20	-1	0	35	540	0.7510
10/7	10	1	-3	-1	7	547	0.7608
10/8	0	0	-4	-1	-5	542	0.7538
10/9	0	0	-6	-1	-7	535	0.7441
10/10	1	0	-2	-1	-2	533	0.7413
10/11	0	1	-2	-3	-4	529	0.7357
10/12	1	0	-4	-2	-5	524	0.7288
10/13	1	0	0	0	1	525	0.7302
10/14	32	8	-2	0	38	563	0.7830
10/15	6	3	0	0	9	572	0.7955
10/16	2	2	0	0	4	576	0.8011
10/17	3	0	-1	0	2	578	0.8039
10/18	2	1	-12	-11	-20	558	0.7761
10/19	24	35	0	-1	58	616	0.8567
10/20	6	7	-3	-6	4	620	0.8623
10/21	0	0	-6	-4	-10	610	0.8484
10/22	0	0	-2	-1	-3	607	0.8442
10/23	0	1	-1	0	0	607	0.8442
10/24	3	2	0	0	5	612	0.8512
10/25	10	12	-1	-1	20	632	0.8790
10/26	12	15	-3	0	24	656	0.9124
10/27	1	0	0	0	1	657	0.9138
10/28	0	0	0	0	0	657	0.9138
10/29	2	0	-2	0	0	657	0.9138
10/30	5	6	0	0	11	668	0.9291
10/31	10	16	-3	-1	22	690	0.9597
11/1	8	8	-2	0	14	704	0.9791
11/2	0	0	0	0	0	704	0.9791
11/3	0	0	-2	0	-2	702	0.9764
11/4	0	0	-1	0	-1	701	0.9750
11/5	0	0	0	0	0	701	0.9750
11/6	0	0	0	0	0	701	0.9750
11/7	0	0	0	0	0	701	0.9750
11/8	4	2	0	0	6	707	0.9833
11/9	2	3	0	0	5	712	0.9903
11/10	1	0	0	0	1	713	0.9917
11/11	0	0	1	0	1	714	0.9930
11/12	3	0	0	0	3	717	0.9972
11/13	1	0	0	0	1	718	0.9986
11/14	0	0	0	0	0	718	0.9986
11/15	0	0	1	0	1	719	1.0000
11/16	0	0	0	0	0	719	1.0000

APPENDIX 4. —Tracking history summaries of coho salmon that were radio-tagged in the Kasilof River during 2007.

Transmitter number	Mid-eye fork length (mm)	Sex	Tagging location (river km)	Tagging date	Stratum	Fate
0342	645	F	23.1	17-Aug	1	Tributary Spawner (Indian Cr.)
3344	640	M	21.4	17-Aug	1	Unknown
6345	560	M	21.9	17-Aug	1	Other Spawner (Crooked Cr.)
3352	640	F	20.5	17-Aug	1	Unknown
0442	510	F	22.9	20-Aug	1	Unknown
0542	540	F	17.8	20-Aug	1	Tributary Spawner (Shantatalik Cr.)
3444	535	F	23.3	20-Aug	1	Unknown
3544	640	M	16.5	20-Aug	1	Tributary Spawner (Nikolai Cr.)
6445	610	F	22.5	20-Aug	1	Unknown
3452	640	F	17.7	20-Aug	1	Unknown
3552	570	M	22.6	20-Aug	1	Tributary Spawner (Shantatalik Cr.)
0642	540	F	22.7	22-Aug	1	Dead/Regurgitated
0742	560	F	18.5	22-Aug	1	Tributary Spawner (Indian Cr.)
0842	575	M	17.8	22-Aug	1	Tributary Spawner (Shantatalik Cr.)
3644	590	F	22.7	22-Aug	1	Mainstem Spawner
3744	565	F	17.1	22-Aug	1	Back Out
3844	520	F	16.5	22-Aug	1	Tributary Spawner (Shantatalik Cr.)
6645	580	F	21.3	22-Aug	1	Back Out
6745	580	M	17.8	22-Aug	1	Tributary Spawner (Nikolai Cr.)
6845	625	M	16.5	22-Aug	1	Unknown
3652	530	F	20.8	22-Aug	1	Tributary Spawner (Nikolai Cr.)
3752	575	M	17.8	22-Aug	1	Mainstem Spawner
3852	595	M	16.0	22-Aug	1	Tributary Spawner (Shantatalik Cr.)
0942	650	M	17.7	4-Sep	2	Dead/Regurgitated
1042	620	F	22.2	4-Sep	2	Mainstem Spawner
1242	530	F	15.5	4-Sep	2	Back Out
3944	520	M	17.8	4-Sep	2	Back Out
4044	630	F	22.2	4-Sep	2	Mainstem Spawner
4144	575	F	16.4	4-Sep	2	Back Out
4244	590	F	15.5	4-Sep	2	Other Spawner (Crooked Cr.)
6945	530	M	17.8	4-Sep	2	Other Spawner (Crooked Cr.)
7045	620	F	18.2	4-Sep	2	Mainstem Spawner
7145	495	M	16.4	4-Sep	2	Back Out
7245	550	F	15.2	4-Sep	2	Back Out
3952	520	M	22.6	4-Sep	2	Unknown
4052	595	F	17.7	4-Sep	2	Unknown
4152	580	F	15.9	4-Sep	2	Mainstem Spawner
1142	495	M	17.8	6-Sep	2	Back Out
1342	615	M	17.8	6-Sep	2	Tributary Spawner (Nikolai Cr.)
1442	535	M	17.8	6-Sep	2	Mainstem Spawner
4344	565	F	17.8	6-Sep	2	Back Out
4444	615	F	16.6	6-Sep	2	Unknown
6545	630	F	22.2	6-Sep	2	Mainstem Spawner
7345	600	F	20.7	6-Sep	2	Back Out

-continued-

APPENDIX 4. —(Page 2 of 3)

Transmitter number	Mid-eye fork length (mm)	Sex	Tagging location (river km)	Tagging date	Stratum	Fate
7445	545	F	16.5	6-Sep	2	Back Out
4252	490	M	17.8	6-Sep	2	Back Out
4352	600	F	21.4	6-Sep	2	Other Spawner (Lower Mainstem)
4452	565	M	16.5	6-Sep	2	Unknown
1542	675	M	17.8	11-Sep	3	Tributary Spawner (Shantatalik Cr.)
1642	635	M	17.8	11-Sep	3	Dead/Regurgitated
1742	615	M	18.5	11-Sep	3	Back Out
1842	640	F	22.5	11-Sep	3	Unknown
1942	640	M	22.2	11-Sep	3	Tributary Spawner (Indian Cr.)
2042	520	F	16.4	11-Sep	3	Other Spawner (Crooked Cr.)
4544	610	F	17.8	11-Sep	3	Back Out
4644	575	F	17.8	11-Sep	3	Back Out
4744	495	F	18.5	11-Sep	3	Dead/Regurgitated
4844	620	M	22.5	11-Sep	3	Mainstem Spawner
4944	660	F	17.0	11-Sep	3	Back Out
5044	580	M	16.5	11-Sep	3	Mainstem Spawner
7545	615	F	17.8	11-Sep	3	Back Out
7645	520	M	17.8	11-Sep	3	Mainstem Spawner
7745	615	M	20.7	11-Sep	3	Back Out
7845	640	F	22.2	11-Sep	3	Unknown
7945	600	F	16.8	11-Sep	3	Back Out
8045	610	M	16.7	11-Sep	3	Mainstem Spawner
4552	640	F	17.8	11-Sep	3	Dead/Regurgitated
4652	590	M	17.8	11-Sep	3	Mainstem Spawner
4752	610	M	22.6	11-Sep	3	Tributary Spawner (Indian Cr.)
4852	550	F	22.9	11-Sep	3	Dead/Regurgitated
4952	590	M	16.4	11-Sep	3	Back Out
5052	575	F	16.7	11-Sep	3	Back Out
2142	635	M	17.7	21-Sep	4	Back Out
2242	595	F	23.1	21-Sep	4	Dead/Regurgitated
5144	610	F	17.7	21-Sep	4	Mainstem Spawner
8145	565	F	18.0	21-Sep	4	Other Spawner (Crooked Cr.)
5152	560	M	22.2	21-Sep	4	Dead/Regurgitated
5244	605	F	22.1	25-Sep	4	Mainstem Spawner
8245	555	F	17.6	25-Sep	4	Other Spawner (Lower Mainstem)
5252	585	F	22.4	28-Sep	4	Back Out
2342	585	F	23.3	4-Oct	5	Dead/Regurgitated
5344	660	M	23.3	4-Oct	5	Other Spawner (Crooked Cr.)
8345	575	M	23.4	5-Oct	5	Mainstem Spawner
5352	510	M	23.4	5-Oct	5	Mainstem Spawner
2442	620	M	23.4	5-Oct	5	Dead/Regurgitated
5444	610	M	23.4	5-Oct	5	Mainstem Spawner
8445	645	F	23.4	5-Oct	5	Mainstem Spawner
5452	660	M	23.4	9-Oct	5	Dead/Regurgitated

-continued-

APPENDIX 4. —(Page 3 of 3)

Transmitter number	Mid-eye fork length (mm)	Sex	Tagging location (river km)	Tagging date	Stratum	Fate
2542	545	M	23.4	9-Oct	5	Dead/Regurgitated
5544	650	M	23.4	9-Oct	5	Back Out
8545	615	M	23.4	9-Oct	5	Unknown
5552	580	M	23.4	9-Oct	5	Mainstem Spawner
2642	660	M	23.4	9-Oct	5	Mainstem Spawner
5644	620	F	23.4	9-Oct	5	Mainstem Spawner
8645	635	F	22.8	10-Oct	5	Mainstem Spawner
5652	640	F	22.8	10-Oct	5	Mainstem Spawner
2742	685	M	22.8	10-Oct	5	Other Spawner (Lower Mainstem)
5744	570	M	22.8	10-Oct	5	Dead/Regurgitated
8745	510	M	22.8	10-Oct	5	Mainstem Spawner
3042	630	M	21.3	12-Oct	5	Dead/Regurgitated
5944	660	F	20.8	12-Oct	5	Unknown
2842	645	M	23.5	15-Oct	5	Mainstem Spawner
2942	575	M	20.7	15-Oct	5	Dead/Regurgitated
5844	620	F	22.4	15-Oct	5	Mainstem Spawner
8845	595	M	22.1	15-Oct	5	Other Spawner (Lower Mainstem)
8945	650	M	21.6	15-Oct	5	Dead/Regurgitated
5752	640	F	23.5	15-Oct	5	Mainstem Spawner
5852	575	M	22.1	15-Oct	5	Mainstem Spawner
5952	550	F	21.0	15-Oct	5	Dead/Regurgitated