U.S. Fish & Wildlife Service

Spawning and Seasonal Distribution of Adult Steelhead in Southcentral Alaska's Kasilof River Watershed from 2007 to 2009

Alaska Fisheries Data Series Number 2010-06

Kenai Fish and Wildlife Field Office
Soldotna, Alaska
June, 2010

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.

Spawning and Seasonal Distribution of Adult Steelhead in Southcentral Alaska's Kasilof River Watershed from 2007 to 2009

Kenneth S. Gates and James K. Boersma

Abstract

Radio telemetry was used to monitor the movements of 159 adult steelhead *Oncorhynchus mykiss* in the Kasilof River watershed from October 2007 to June 2009. Steelhead were radio-tagged between river kilometer 10 and 24 and tracked throughout the watershed using fixed receiver stations, boats, and fixed-wing aircraft. Sixty-two percent (*N*=99) spawned in either tributaries or the mainstem Kasilof River. Spawning tributaries included Coal, Crooked, Nikolai, Indian, and Shantatalik creeks. The remaining 60 fish were classified as "Dead/Expelled" (*N*=19), "Back-out" (*N*=29), "Non-spawner" (*N*=5), or "Unknown" (*N*=7). The seasonal distribution and movements of radio-tagged steelhead were described by dividing the watershed into five regions: the estuary, river, outlet, lake, and tributaries. Distribution varied as fish moved among regions throughout the study period. The majority (60% to 63%) of the fish remained in the river throughout the fall before dispersing to their overwintering areas. Overwintering areas included the river, outlet, lake and estuary regions. Regions used as migration corridors increased in importance by April as fish began to move to their respective spawning locations. Movements of radio-tagged steelhead continued to increase throughout the spring as spawning commenced and kelts began to migrate back to saltwater. Movement among regions was highest during May and June but was observed during all months.

Introduction

Crooked and Nikolai creeks are the only two tributary streams in the Kasilof River watershed that support steelhead *Oncorhynchus mykiss* according to the Anadromous Waters Catalog (Johnson and Daigneault 2008). Crooked Creek historically supported a small wild run of steelhead estimated to consist of a maximum of several hundred fish (Gamblin et al. 2004). The Alaska Department of Fish and Game (Department) enhanced this run beginning in the 1980s to provide additional angling opportunity. Enhancement efforts created a fishery unique from other steelhead fisheries on the Kenai Peninsula because it provided anglers an opportunity to harvest fish. Sport catches of steelhead in the Kasilof River and Crooked Creek peaked during the mid-1990s and averaged 5,836 fish between 1993 and 1995 (Mills 1994; Howe et al. 1995, 1996). During the same period, harvest of steelhead averaged 1,397 fish annually. Higher catches during this period were a direct result of the enhancement program. The enhancement program was terminated in 1993 after concerns were raised about straying of hatchery steelhead into the Kenai River. Since termination of the enhancement program, catch has declined and has averaged 632 fish for the last 10 years between 1999 and 2008 (Gamblin et al. 2004; Jason Pawluk, Alaska Department of Fish and

Authors: The authors can be contacted through the U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Field Office, 43655 Kalifornsky Beach Rd., Soldotna, Alaska, 99669; or kenneth_gates@fws.gov and james_boersma@fws.gov.

Game, personal communication). Anticipating a decline in the number of steelhead available to anglers, the Alaska Board of Fisheries restricted the fishery within Crooked Creek and the Kasilof River below the Sterling Highway Bridge to catch-and-release only beginning in 1996.

Current regulations allow steelhead fishing in Crooked Creek, the mainstem Kasilof River, and Nikolai Creek. For Crooked Creek, fishing is allowed from August 1 through December 31, and only unbaited, single hook, artificial lures may be used between September 15 and December 31. In addition, no retention of rainbow trout *O. mykiss* or steelhead is allowed from Crooked Creek. For the Kasilof River, from the mouth to the Sterling Highway Bridge, fishing is allowed from September 1 through June 30 with one unbaited, single hook, artificial lure. Additionally, bait may be used with one single hook from May 16 through June 30. Like Crooked Creek, no retention of rainbow trout or steelhead is allowed in the Kasilof River below the Sterling Highway Bridge. For the Kasilof River above the Sterling Highway Bridge and Nikolai Creek, fishing is open year-round for rainbow and steelhead. The daily bag limit is 2 per day/2 in possession with only one fish exceeding 20 inches in length, and only 2 fish over 20 inches can be harvested annually. Harvest has averaged 18 fish annually from 1996 to 2008 based on Statewide Harvest Surveys (Howe et al. 2001 a-d; Walker et al. 2003; Jennings et al. 2004, 2006a, 2006b, 2007, 2009a, and 2009b; Jason Pawluk, Alaska Department of Fish and Game, personal communication).

Migrations of adult steelhead into freshwater are divided into two run components characterized by timing and physiology. The summer/fall run generally returns to freshwater between May and October and consists of steelhead with undeveloped gonads, while the winter run returns between November and April and consists of steelhead with developed gonads (Smith 1969; Barnhart 1986; Robards and Quinn 2002). Like other steelhead populations in southcentral Alaska, steelhead returning to the Kasilof River watershed are considered fall-run fish, entering freshwater between mid-August and November and over-wintering before spawning in tributaries during May and June (Wallis and Balland 1982, 1983, and 1984; Larson and Balland 1989, and Begich 1997). The presence of a winter run to the Kasilof River has not been documented. The emigration of spawned-out steelhead (kelts) from the Kasilof River watershed is thought to follow a similar pattern to that observed in the Ninilchik River, another steelhead stream located in southcentral Alaska. The emigration of kelts passing downstream through a weir on the Ninilchik River occurs during spring and has been observed to start as early as 19 May, in 2000, and as late as 12 June, in 2001 (U.S. Geological Survey, unpublished data).

Steelhead from the Kasilof River watershed are thought to follow the same life history pattern described for other coastal wild steelhead populations in the Pacific Northwest. Steelhead in these populations sometimes survive to make two spawning migrations and up to five have been recorded (Bali 1959, Lindsay et al. 1991). Repeat spawners are predominately female due to higher post-spawning mortality among males (Shapovalov and Taft 1954; Chapman 1958; Withler 1966; Burgner et al. 1992). Higher mortality in males is attributed to their longer time on the spawning grounds and greater physical exertion due to the longer spawning periods, mating with multiple females, and combat with other males (Meigs and Pautzke 1941; Jones 1974). Wild steelhead primarily smolt at age 3 and return to spawn after 2 years in saltwater (Sanders 1985), whereas steelhead reared in hatcheries usually smolt after 1 year (Chapman 1958, Lindsay et al. 1991) and rarely spawn more than once. Although the steelhead run in Crooked Creek was once enhanced through hatchery operations, adults captured during the 2004-2006 spawning seasons exhibited life-history characteristics more similar to wild steelhead (Gates and Boersma 2009).

The overwintering distribution of steelhead in the Kasilof River watershed was poorly understood prior to 2008. Steelhead were thought to overwinter in the mainstem river, as indicated by harvest and catch information (Gamblin et al. 2004) and the observed spring spawning migration into Crooked Creek (Gates and Palmer 2006a, 2006b, 2008; Gates and Boersma 2009). The radio telemetry study conducted by the U.S. Fish and Wildlife Service (Service) in 2008 provided the first reliable documentation of steelhead overwintering areas in the Kasilof River watershed, and showed that steelhead overwintered in the mainstem Kasilof River upstream of the Sterling Highway Bridge, the Kasilof River near the outlet of Tustumena Lake, and Tustumena Lake (Gates 2009).

The Service's first project to address informational gaps related to steelhead in the Kasilof River watershed was a weir operated in Crooked Creek during 2004. Since then, weirs equipped with underwater video systems have been installed and operated in Crooked and Nikolai creeks. Objectives of this work were to estimate the abundance and run timing of steelhead and to collect age, sex, length, and genetic information. Combined weir counts have ranged from 463 to 1,465 steelhead between 2005 and 2008 (Gates and Palmer 2006a, 2006b, and 2008; Gates and Boersma 2009). Spawning populations other than Crooked and Nikolai creeks were unknown prior to the 2008 radio telemetry study (Gates 2009).

In January 2006, the Federal Subsistence Board determined that residents of Ninilchik, Alaska, qualified for customary and traditional use of salmon, trout, Dolly Varden *Salvelinus malma* and other char species in Federal waters within the Kasilof River watershed. This finding led to adoption of new regulations for 2007 and 2008 that expanded the methods and means, seasons, and harvest limits for salmon and other fish species in these Federal subsistence fisheries. Along with the establishment of annually occurring salmon fisheries that allowed use of dip net and rod and reel gear, provisions were included for a temporary three-year salmon fishery that allowed use of one fish wheel in the upper Kasilof River. To better assess effects of these new fisheries on steelhead populations, managers needed more detailed information on the abundance and distribution of steelhead within the Kasilof River watershed. To obtain some of this needed information, we obtained funding through the Office of Subsistence Management's Fisheries Resource Monitoring Program to use radio telemetry to describe the spawning and seasonal distribution of fall-run steelhead throughout the Kasilof River watershed.

Specific objectives of the project were to (1) describe the freshwater migratory patterns and overwintering distribution of radio-tagged adult steelhead which enter the Kasilof River during the fall; and (2) identify spawning areas selected by radio-tagged steelhead. Results from steelhead tagged in 2007 during an initial study (Gates 2009) as well as steelhead tagged in 2008 during the current study are provided in this report. Information collected from this work greatly improves our understanding of seasonal movements of adult steelhead in the Kasilof River watershed and will be useful in evaluating and refining management strategies.

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 that drain Refuge lands enter Tustumena Lake except Crooked Creek, which flows directly into the Kasilof River (Figure 1). Several species of salmon, trout, char, and whitefish use this watershed for spawning and rearing habitat (Johnson and Daigneault 2008), including Chinook *O. tshawytscha*, coho *O. kisutch*, sockeye *O. nerka*, and pink salmon *O. gorbuscha*, rainbow trout, steelhead, Dolly Varden, lake trout *S. namaycush*, and round whitefish *Prosopium cylindraceum*.

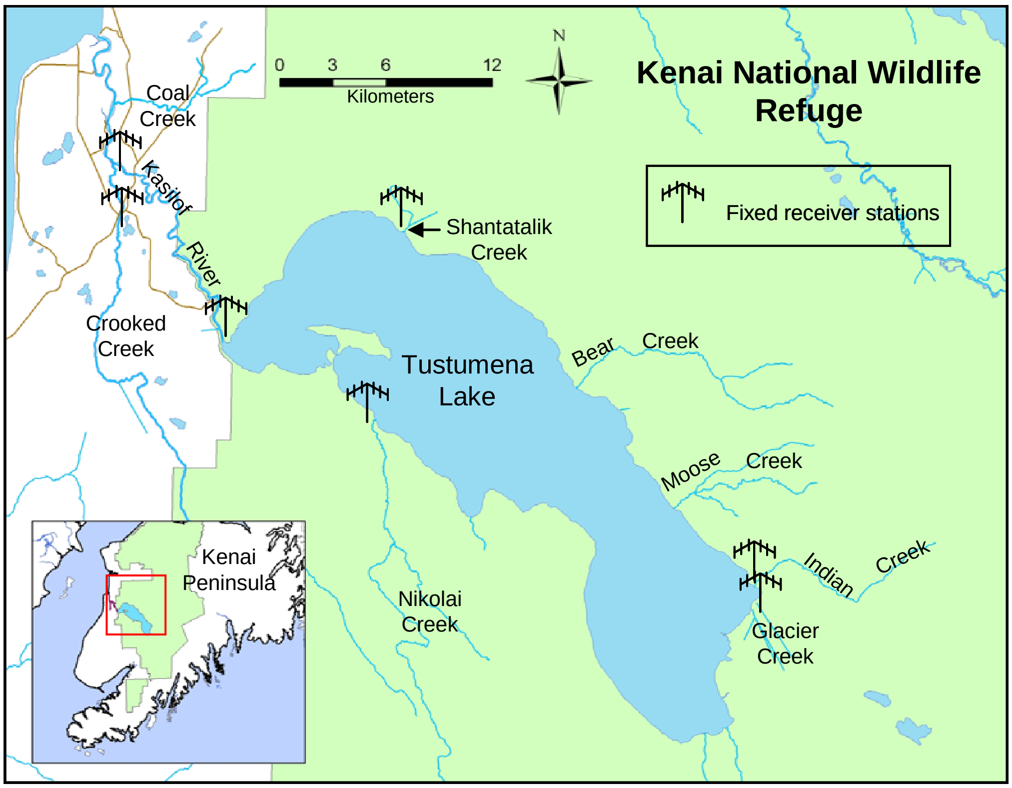

FIGURE 1.—Map of the Kasilof River watershed and the locations of fixed receiver stations between 2007 and 2009.

Methods

Radio Telemetry

Radio telemetry was used to uniquely identify and track movements of individual adult steelhead throughout the Kasilof River watershed. Movements of radio-tagged steelhead were documented using a combination of fixed data-logging receiver stations and mobile tracking using boats and fixed-wing aircraft.

Fish Capture.—Drift gillnets were actively fished between river kilometer (rkm) 9 and 24 during 2007 and rkm 18 and 24 during 2008 to capture steelhead for radio tagging. Methods for deploying gillnets were similar to those used to capture coho salmon for radio telemetry studies in the Holitna, Kenai, and Kasilof rivers (Chythlook and Evenson 2003; Carlon and Evans 2007; Palmer et al. 2008; Gates et al. 2009). A two to three person crew deployed a single gillnet from a 5.5-m boat. One crew member piloted the boat while the other crewmember(s) positioned on or near the bow of the boat tended the net. Gillnets were constructed from Miracle® (MS-30) brand twisted nylon webbing. Each gillnet fished was made with 11.4-cm stretched mesh and was 12.2-m long 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. Once a fish became entangled in the net, the net was immediately pulled from the water and the fish was brought on board the boat. The portion of net containing the fish was placed in a large tote filled with river water in which the fish was disentangled or cut from the net. Once freed from the net, steelhead were inspected for condition and either released or transported to a nearby onshore tagging station. These methods minimized stress associated with capture and handling.

Radio Tagging.—Steelhead were surgically implanted with radio transmitters between 4 and 16 October 2007 (*N*=79) and 9 September and 11 October 2008 (*N*=80). Radio transmitters were manufactured by Lotek Wireless Incorporated® (Model SR-M11-25), measured 11 x 54 mm, were digitally encoded, equipped with a motion sensor, and outfitted with a 609 d battery. Radio transmitters weighed 9.7 g in air and did not exceed 2% of the fish's body weight (Winter 1983). One transmitter failed prior to deployment during 2007 and the remaining 159 transmitters were dispersed over four radio frequencies between 162.319 and 162.381 MHz. All radio-tagged steelhead received a Floy® T-Bar anchor tag (Model FD-94) as secondary identification.

Surgical procedures were similar to those described by Palmer (1998) and Summerfelt and Smith (1990). A stock solution of 100 g tricaine methanosulfate (MS-222) to one liter of water was diluted to 60 mg/L to anesthetize fish receiving a radio transmitter. The concentration of the anesthesia was sometimes altered according to reactions of each fish during anesthetizing, but never exceeded 70 mg/L. Once fish were anesthetized, a measurement from the mid-eye to fork length was taken to the nearest 5 mm. The fish was then placed ventral side up in a cradle and irrigated with a combination of anesthesia water and plain river water throughout the surgical procedure. A 3 to 4 cm incision large enough to accommodate the transmitter was made anterior to the pelvic girdle approximately one centimeter from the midventral axis. The transmitter antenna was then routed under the pelvic girdle and through the body wall slightly off the midventral axis and anterior to the vent using a 25.4-cm hypodermic needle and grooved director. The incision was closed with three or four individual stitches of absorbable suture material and additionally secured with Vetbond™ tissue adhesive. After surgery, fish were immediately placed in a large tote with circulating river water to regain their equilibrium prior to being released near the capture site. A Floy® T-Bar anchor tag was applied near the base of the dorsal fin once the fish was placed in the recovery tote. Surgical instruments and transmitters were soaked in ChlorhexiDerm™ S disinfectant and rinsed in saline solution before each use.

Radio Tracking.—Radio telemetry receivers manufactured by Lotek Wireless Incorporated® were used for all fixed station and mobile tracking. Fixed receiver stations were used to automatically identify and record radio-tagged fish at the mouths of Nikolai, Glacier (2007 only), Indian, Shantatalik, and Crooked creeks, the lake outlet, and at the Department's Crooked Creek facility (May and June 2008 only) (Figures 1 and 2). The Nikolai Creek station was removed between November 2007 and April 2008 because of limited access, while all other fixed receiver stations were operated from at least October through June between 2007 and 2009. Fixed receiver stations were similar to those used on the Kenai River to monitor rainbow trout movements (Palmer 1998) and on the Kasilof River to monitor coho salmon (Palmer et al. 2008). Each station was comprised of two Yagi antennas, antenna masts, solar panel(s), and a strongbox housing a single data-logging receiver, an antenna switch box, three 12-volt deep cycle batteries, and a voltage regulator.

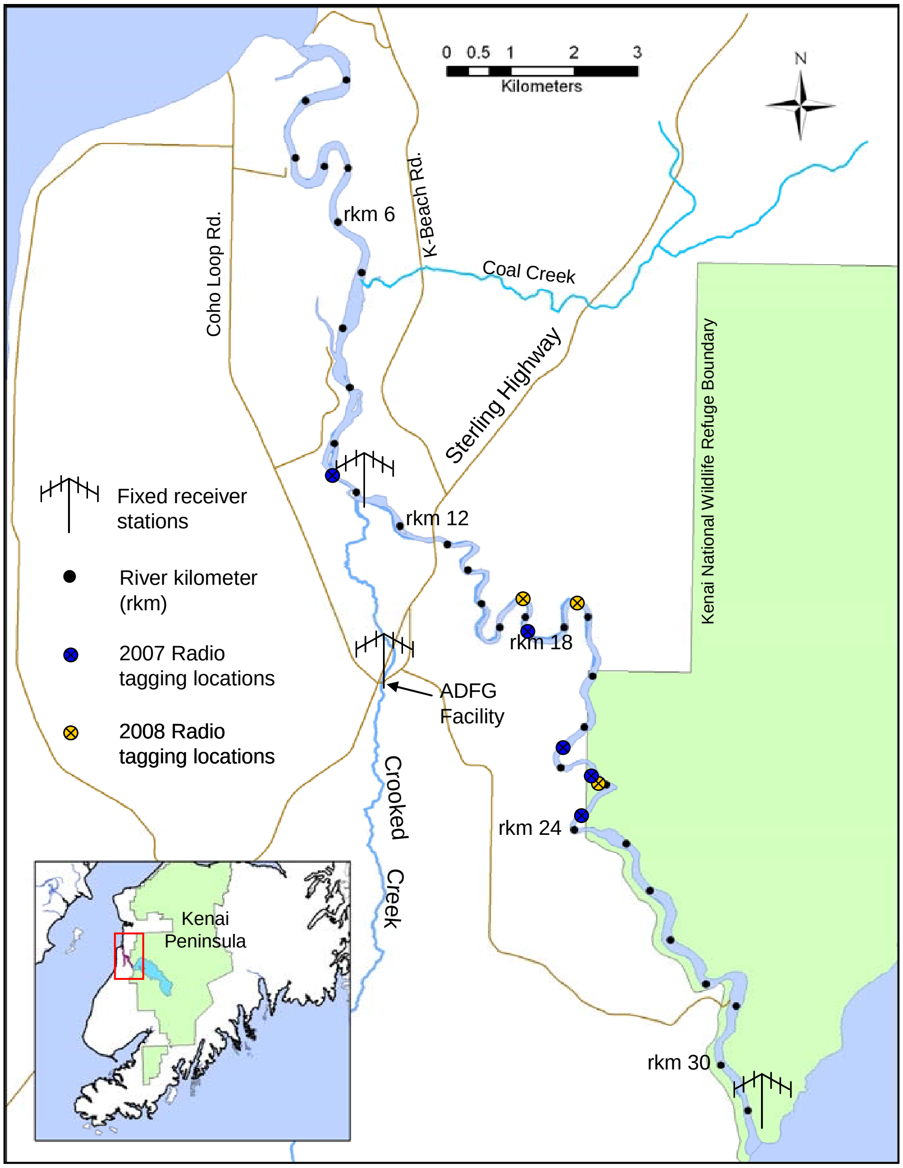

FIGURE 2.—Map of the Kasilof River and lower Crooked Creek illustrating the locations of fixed receiver stations between 2007 and 2009. The station located at the Department's facility (ADFG facility) was only operated during the spring of 2008.

Mobile tracking was used to extend geographical monitoring coverage and obtain more detailed information on movement patterns of radio-tagged steelhead. Boat tracking was conducted on the Kasilof River each week from the lake outlet to tidewater between 11 October and 29 November 2007, 5 May and 17 June 2008, 19 September and 9 December 2008, and 15 April and 30 June 2009. Aerial surveys were flown monthly at approximately 300 to 400 m above the ground using a Cessna 185, PA-18 Supercub, or Found Bushhawk fixed-wing aircraft between 18 October 2007 and 23 June 2008 and 19 December 2008 and 19 June 2009. The frequency of flights was dependent on pilot availability and movement of radio-tagged steelhead obtained from fixed receiver stations and boat surveys. Winter flights took place over the mainstem Kasilof River and Tustumena Lake shoreline, while spring flights shifted to tributary streams and the mainstem Kasilof River during the spring spawning season. A portable global positioning system (GPS) was used during all mobile tracking surveys to accurately identify the latitude and longitude of each located fish.

Data Analysis

Radio telemetry information collected with the various tracking methods was integrated into one database for each study period that stored the tagging/release date and location, all logged data transmission dates and locations, and the final inferred fate of each radio-tagged steelhead. Locations identified during mobile tracking events were recorded as latitude and longitude coordinates (WGS84 datum). Each radio-tagged fish was assigned one of six possible final fates based on information collected throughout each study period (Table 1). There were two nine month study periods: October 2007 to June 2008, and October 2008 to June 2009. Each study period was further categorized into three seasons: fall (October and November), winter (December - March), and spring (April - June).

Spawning locations and survival of radio-tagged steelhead were determined from tracking results. A radio-tagged fish that migrated to a particular location and remained in the area for an extended period of time without activating the mortality sensor was considered to have reached its spawning location. A radio-tagged fish that remained in one location for an extended period with an activated mortality sensor was considered to be dead. A radio-tagged steelhead that remained in freshwater beyond 23 June 2008 or 30 June 2009, the last days of mobile tracking for each study period, and whose mortality sensor was not activated was considered to have survived the spawning event.

TABLE 1.—Possible fates of steelhead radio tagged in the Kasilof River watershed during 2007 and 2008.

Fate	Description
Spawner	A fish that spawns in the Kasilof River watershed.
Dead/Expelled	A fish that did not complete its spawning migration because it has died or has expelled 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 prior to the spawning period.
Non-spawner	A fish that has overwintered in the Kasilof River watershed, exhibited no signs of spawning based on abnormal movements, and returned to saltwater early in the spawning season.
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 dates and duration of spawning and kelt emigration were determined only for radio-tagged steelhead that spawned in Crooked Creek and Tustumena Lake tributaries. Spawners in the mainstem Kasilof River and Coal Creek were omitted from this analysis. Entry and exit times could not be determined for mainstem Kasilof River spawners since most of them also overwintered in the Kasilof River, which made it difficult to determine when spawning began. Entry and exit times could not be determined for Coal Creek spawners since there was no fixed receiver station near its mouth. All radio-tagged steelhead that died in tributary streams and kelts that died in the mainstem Kasilof River or Tustumena Lake after leaving spawning tributaries were also omitted from this analysis. All steelhead spawning in Tustumena Lake tributaries were analyzed as a single group because only a few radio-tagged fish were located in each lake spawning tributary. The fixed receiver station located at the mouth of Crooked Creek was operated through 30 June during 2008 and 2009, marking the last day for potential detections of radio-tagged kelts in the lower Kasilof River. Mobile tracking was completed on 23 June and 30 June during 2008 and 2009, respectively. All kelts that were detected prior to or on 30 June were included in the mainstem Kasilof River and Tustumena Lake kelt emigration analysis. Radio-tagged steelhead remaining above Crooked Creek after 30 June were omitted from the analysis because tracking had ceased.

The duration of spawning was defined as the number of days a radio-tagged steelhead remained in a tributary between its first and last detection by a fixed receiver station located near the tributary mouth. The kelt emigration period from tributaries was estimated using the first date a radio-tagged kelt was detected leaving a spawning tributary to the last date a kelt was detected. After kelts passed fixed receiver stations near the mouths of respective spawning tributaries, the remainder of the emigration period was estimated using fixed receiver stations and mobile tracking. The duration of this period of the emigration was estimated as the number of days between the date a radio-tagged kelt emigrated from a spawning tributary until it was last detected below Crooked Creek.

Seasonal movements and distributions of radio-tagged steelhead were described monthly by dividing the Kasilof River watershed into five regions consisting of the estuary, river, outlet, lake, and tributaries (Table 2). Each region represented different habitats available to steelhead. Radio-tagged fish were located and assigned to one or more regions during each month from October to June. A radio-tagged fish detected within a region during a single month was included in the analysis and was assigned a unique detection regardless of the total number of observations recorded for that month. Since there were only five regions, a total of five unique detections were possible during a single month for an individual radio-tagged fish. The distribution by region was calculated as a percent of the total observed unique detections for each month (Table 3).

The number of radio-tagged steelhead traveling among regions during each month was used to describe seasonal movements. The amount of movement among regions was estimated as a percentage by dividing the difference of the total unique detections and active radio transmitters by the total active radio transmitters. This percentage increased as more radio-tagged fish traveled among regions (Table 3). The calculated percentage could exceed 100%, if several fish moved among multiple regions within a single month. This was most likely to occur during the spring period when steelhead migrated from overwintering areas to spawning locations.

TABLE 2.—Regions of the Kasilof River watershed used to describe seasonal movements and distributions of radio-tagged steelhead between 2007 and 2009.

Region	Description
Estuary	Area of the mainstem Kasilof River below Crooked Creek to Cook Inlet
River	Area of the mainstem Kasilof River above Crooked Creek to rkm 30.5
Outlet	Area at the outlet of Tustumena Lake within a one kilometer radius of the outlet fixed receiver station
Lake	Tustumena Lake
Tributary	Any tributary flowing into Tustumena Lake or the Kasilof River

TABLE 3.—An example of how movement and distribution were calculated for radio-tagged steelhead traveling among regions during each month in the Kasilof River watershed.

	Unique detections in October	Distribution by region (%)	Unique detections in November	Distribution by region (%)
Regions				
River	10	(10/20)*100 = 50	10	40
Lake	5	(5/20)*100 = 25	10	40
Outlet	5	(5/20)*100 = 25	5	20
Estuary	0	(0/20)*100 = 0	0	0
Tributary	0	(0/20)*100 = 0	0	0
Total unique detections	20		25	
Total active radio transmitters	15		10	
Difference between total unique detection and total active radio transmitters	5		15	
Percent movement among regions	(5/15)*100 = 33		150	

Results

Adult steelhead were radio-tagged in the Kasilof River between 4 and 16 October 2007 (*N*=79) and 9 September and 11 October 2008 (*N*=80) (Appendices 1 and 2). In 2007, all radio-tagged steelhead were captured between rkm 10 and 24 and then transported to one of five locations for tagging (Figure 2). Similarly, steelhead radio tagged in 2008 were captured between rkm 18 and 24 and then transported to one of three locations (Figure 2). Tagging locations were chosen based on being easily accessible by boat and having enough dry ground for setting up surgical equipment. Females comprised 54% (*N*=43) of the radio-tagged steelhead in 2007 and 76% (*N*=61) in 2008. Tagged females had a mean length of 651 mm (range, 540 mm to 780 mm) in 2007, and a mean length of 673 mm (range, 525 mm to 780 mm) in 2008. Tagged males had a mean length of 634 mm (range, 510 mm to 785 mm) in 2007, and 633 mm (range, 490 mm to 735 mm) in 2008.

Radio-tagged steelhead were tracked throughout the fall, winter, and spring. Most fixed receiver stations were operated and maintained between September and June during each study period, although receiver stations were not activated until October in 2007 because tagging did not begin until 3 October. Station data were periodically downloaded throughout the fall, winter, and spring months. Boat tracking events occurred 18 times between 11 October 2007 and 17 June 2008, and 26 times between 19 September 2008 and 30 June 2009. Nearly all boat tracking events were conducted between the lake outlet and tidewater, with the exception of those that occurred during late fall and early spring. These surveys were conducted between the lake outlet and the boat launch immediately upstream of the Sterling Highway because of low water conditions. Aerial tracking events occurred 16 times between 18 October 2007 and 23 June 2008, and 18 times between 19 October 2008 and 19 June 2009.

Each radio-tagged steelhead was assigned a final "fate" based on information collected between the date it was tagged and the following June (Table 4). Ninety-nine radio-tagged steelhead (54 in 2007/2008; 45 in 2008/2009) spawned either in a tributary (*N*=81) or the mainstem Kasilof River (*N*=18) and were assigned the fate of "Spawner". The spawning tributaries selected by these fish were Crooked (*N*=57), Nikolai (*N*=14), Coal (*N*=6), Indian (*N*=2), and Shantatalik (*N*=2) creeks. Spawning destinations could not be determined for 38% of radio-tagged steelhead; these fish were assigned fates of "Dead/Expelled", "Back-out", "Non-spawner" or "Unknown". Nineteen fish (12%) were assigned the fate "Dead/Expelled. Twenty-nine fish (18%) left the watershed before the spawning period and were assigned the fate "Back-out" (Tables 4 and 5). Most of these "Back-out" fish were female and were last detected two or three weeks after tagging. One of these "Back-out" fish, tagged during 2008, was relocated during a 2008/2009 winter aerial survey near the mouth of Stariski Creek, which is about 67 km south of the Kasilof River mouth. During this same aerial survey, another "Back-out" fish was detected near the mouth of the Anchor River, which is about 79 km south of the Kasilof River mouth. However, the radio transmitter on this fish could not be decoded by the receiver, probably because the fish was in saltwater. The remaining 12 fish were assigned a fate of "Non-spawner" or "Unknown". The "Non-spawners" remained in freshwater and overwintered but did not show any indications of spawning in the Kasilof River watershed the next spring. The "Unknown" fish resided in freshwater for varying lengths of time prior to the spawning season and then were never detected again either within or leaving the watershed.

TABLE 4.—Final fates of adult steelhead radio-tagged in the Kasilof River during 2007 and 2008.

2007/2008 Fate		Male	Female	Total	Percent
Spawner					
	Mainstem Kasilof River	2	4	6	7.6
	Coal Creek	1	2	3	3.8
	Crooked Creek	21	16	37	46.8
	Nikolai Creek	5	1	6	7.6
	Indian Creek	0	2	2	2.5
		29	25	54	68.4
Dead/Expelled					
	Spring mortality	2	4	6	7.6
	Fall and overwinter mortality	1	7	8	10.1
		3	11	14	17.7
Harvested		0	0	0	0.0
Back-out		2	4	6	7.6
Non-spawner		2	3	5	6.3
Unknown		0	0	0	0.0
Total		36	43	79	100.0

2008/2009 Fate		Male	Female	Total	Percent
Spawner					
	Mainstem Kasilof River	4	8	12	15.0
	Coal Creek	2	1	3	3.8
	Crooked Creek	7	13	20	25.0
	Nikolai Creek	3	5	8	10.0
	Shantatalik Creek	1	1	2	2.5
		17	28	45	56.3
Dead/Expelled					
	Spring mortality	0	0	0	0.0
	Fall and overwinter mortality	0	5	5	6.3
		0	5	5	6.3
Harvested		0	0	0	0.0
Back-out		2	21	23	28.8
Non-spawner		0	0	0	0.0
Unknown		0	7	7	8.8
Total		19	61	80	100.0

TABLE 5.—Summary of radio-tagged steelhead backing out of the Kasilof River watershed during 2007 and 2008.

Tagging Period	*N*	Number of "Backout"	Mean (d)	Range (d)	SE	Range of last detection date
2007						
October	79	6	17	9 – 27	2.9	18-Oct – 30-Oct
2008						
September	40	16	18	4 – 72	4.8	16-Sep – 20-Nov
October	40	7	21	6 – 37	3.5	8-Oct – 7-Nov
Total	80	23	19	4 – 72	3.5	16-Sep – 20-Nov

The distribution of radio-tagged steelhead varied as fish moved among regions throughout the study period. Most were located in the river during October and November (Figure 3). Overwintering occurred primarily in the river, lake, and outlet regions during both study periods. Radio-tagged steelhead began to move from their overwintering locations to spawning areas during April as the May-June spawning season approached. The distribution of fish during spring decreased in all regions from winter averages with the exception of the estuary and tributaries; distribution in these two regions increased from an average of less than 3% to 47%.

Radio-tagged steelhead assigned “Spawner” fates primarily overwintered in the river, outlet, and lake regions (Table 6). Three fish during the 2008/2009 study period used the estuary as an overwintering area. Nearly all Tustumena Lake tributary spawners (*N*=18) overwintered in the lake and outlet regions, whereas Crooked Creek, Coal Creek, and mainstem Kasilof River spawners (*N*=81) overwintered primarily in the river and outlet regions.

The percent movement of radio-tagged steelhead traveling among regions ranged from 32% to 185% between October 2007 and June 2008, and from 8% to 104% between October 2008 and June 2009 (Figure 4). The least movement among regions occurred during March 2008 and December 2008, while the most movement occurred during May for each study period. For both study periods, the average movement was 52% during fall, 45% during winter, and 118% spring periods. Average movement for each of the seasons was less during 2008/2009 than during 2007/2008.

Pre-spawning and spawning survival was estimated using information from all radio-tagged steelhead except those with “Backout” fates (*N*=29). Pre-spawning survival, determined from steelhead assigned “Spawner”, “Dead/Expelled”, “Non-spawner”, and “Unknown” fates, was 81% for the 2007/2008 study period and 91% for the 2008/2009 study period. Radio-tagged fish assigned “Dead/Expelled” fates were further classified as either spring or fall/winter mortality. All steelhead classified as a spring mortality survived to the beginning of the spawning season, while all fall/winter mortalities died by 12 February. Steelhead assigned an “Unknown” fate during 2008 and 2009 were assumed to have survived to the spawning season even though contact with these fish was lost prior to the spawning season. During the pre-spawning period, males exhibited higher survival during both study periods (91% in 2007/2008; 100% in 2008/2009) than females (72% in 2007/2008; 88% in 2008/2009) (Table 4). Survival of all spawning radio-tagged steelhead, fish that remained in freshwater through 23 June 2008 and 30 June 2009 and whose transmitter was emitting an active signal, was 76% in 2008 and 67% in 2009 (Table 7). Of these spawning steelhead, female survival (92% in 2008; 82% in 2009) was much greater than male survival (62% in 2008; 41% in 2009).

FIGURE 3.—Percent of radio-tagged steelhead distributed by month for each region in the Kasilof River watershed between 2007 and 2009. Dashed lines denote seasonal averages of distribution for each region during each study period.

TABLE 6.—Winter distribution by spawning location for radio-tagged steelhead in the Kasilof River watershed during 2008 and 2009.

		Estuary		River		Outlet		Lake		
Spawning Locations	Spawners (*N*)	Number of Fish Detected	Distribution (%)	Number of Fish Detected	Distribution (%)	Number of Fish Detected	Distribution (%)	Number of Fish Detected	Distribution (%)	Total Unique Detections
2007/2008										
Mainstem	6	0	0	4	44.4	4	44.4	1	11.1	9
Coal Creek	3	0	0	1	25.0	2	50.0	1	25.0	4
Crooked Creek	37	0	0	16	25.8	22	35.5	24	38.7	62
Nikolai Creek	6	0	0	1	10.0	3	30.0	6	60.0	10
Indian Creek	2	0	0	0	0.0	2	50.0	2	50.0	4
Total	54			22		33		34		89
2008/2009										
Mainstem	12	1	5.9	10	58.8	3	17.6	3	17.6	17
Coal Creek	3	1	16.7	3	50.0	1	16.7	1	16.7	6
Crooked Creek	20	1	3.4	18	62.1	8	27.6	2	6.9	29
Nikolai Creek	8	0	0.0	2	20.0	2	20.0	6	60.0	10
Shantatalik Creek	2	0	0.0	0	0.0	0	0.0	2	100.0	2
Total	45	3		33		14		14		64

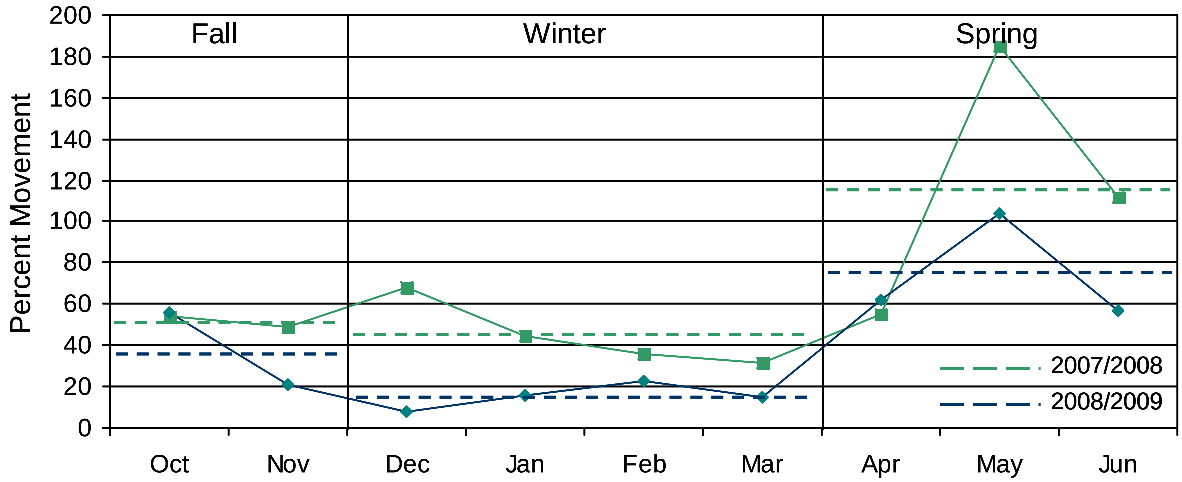

FIGURE 4.—Percent movement of radio-tagged steelhead traveling among regions during each month in the Kasilof River watershed from 2007 to 2009. Dashed lines represent the average movement during each season.

Estimates of the spawning period duration, timing of kelts egressing tributaries, and kelt emigration from Tustumena Lake and mainstem Kasilof River were limited to steelhead spawning in Crooked Creek and Tustumena Lake tributaries. On average, radio-tagged steelhead remained in Crooked Creek for 26.8 d in 2008 (*N*=30; range, 6-42 d) and 18.3 d in 2009 (*N*=15; range, 3-35 d), during the 26 April to 21 June spawning season before returning to the Kasilof River (Table 8). Residence times of lake tributary spawners were similar to those for Crooked Creek each year with averages of 23.8 d in 2008 (*N*=6; range, 8-33 d) and 18.3 d in 2009 (*N*=7, range, 3-40 d). Kelts emigrated from Crooked Creek and the lake tributaries from 12 May to 23 June (Figure 5; Table 8). The kelt emigration from Crooked Creek began and ended (16 May-21 June 2008, 12 May-15 June 2009) earlier than the emigration from lake tributaries (29 May-23 June 2008, 21 May-22 June 2009), and the emigration from both locations began and ended later in 2008 than in 2009. Upon emigrating from spawning areas, Crooked Creek kelts traveled on average for 7.6 d (range, 1-16 d) in 2008 and 7.0 d (1-21 d) in 2009 before entering brackish water, while kelts from Tustumena

Lake tributaries traveled on average for 16.7 d (range, 9-31 d) in 2008 and 22.0 days (range, 12-26 d) in 2009.

TABLE 7.—Number of radio-tagged steelhead which survived spawning in the Kasilof River watershed during 2008 and 2009.

	Mainstem		Coal		Crooked		Nikolai		Indian		Shantatalik		Total				
	Survived	Died	Survived	Died	Survived	Died	Survived	Died	Survived	Died			Survived	Died	Total	% Survival	% Mortality
2008[a]																	
Male	0	2	1	0	14	7	3	2	0	0			18	11	29	62.1	37.9
Female	4	0	2	0	14	2	1	0	2	0			23	2	25	92.0	8.0
Total	4	2	3	0	28	9	4	2	2	0			41	13	54	75.9	24.1
2009[a]																	
Male	1	3	1	1	4	3	0	3			1	0	7	10	17	41.2	58.8
Female	7	1	0	1	11	2	4	1			1	0	23	5	28	82.1	17.9
Total	8	4	1	2	15	5	4	4			2	0	30	15	45	66.7	33.3

[a] Any radio-tagged steelhead that remained in freshwater through 23 June (2008) and 30 June (2009) and whose transmitter was emitting an active signal was considered to have survived the spawning event.

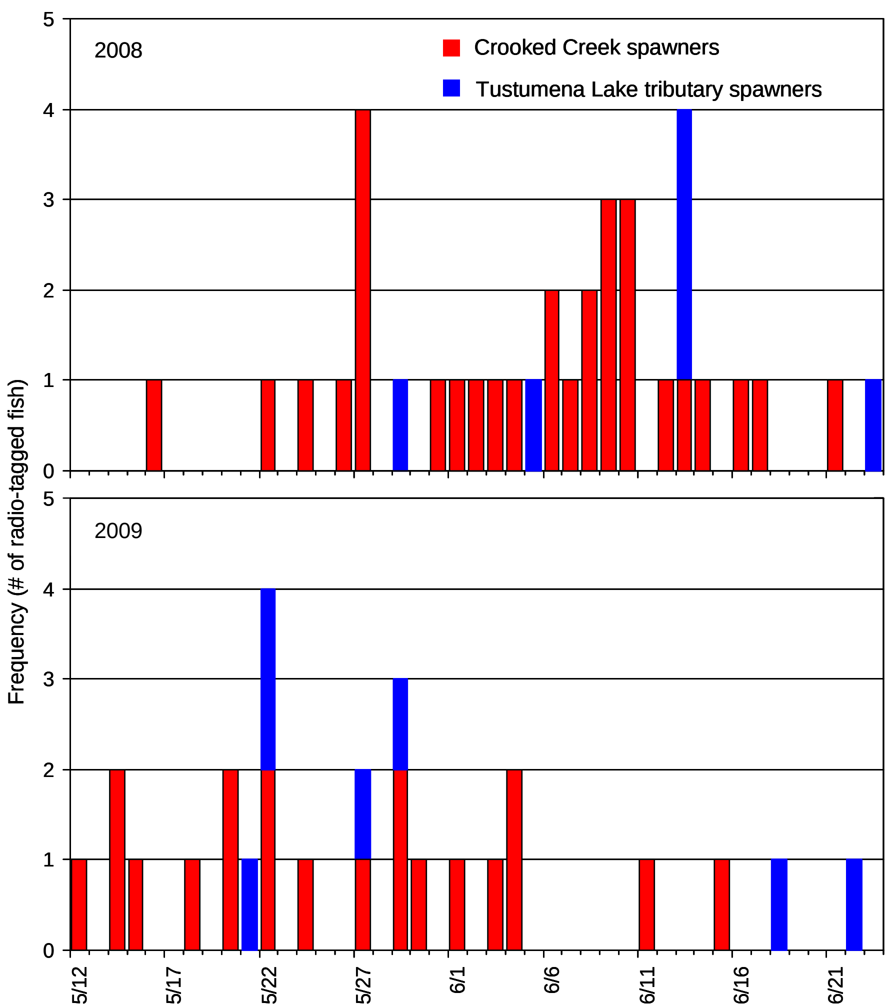

FIGURE 5.—Number of radio-tagged steelhead emigrating from spawning tributaries each day between 12 May and 23 June during 2008 and 2009.

TABLE 8.—Duration of spawning season, timing of kelt emigration from spawning areas, and duration of kelt emigration for radio-tagged steelhead entering Crooked Creek and Tustumena Lake tributaries to spawn during 2008 and 2009.

Year and Event		Crooked Creek	Tustumena Lake
2008			
Spawning Period	*N* [a]	30	6
	Dates[b]	26 Apr - 21 Jun	14 May - 23 Jun
	Mean (d)	26.8	23.8
	Range (d)	6 - 42	8 - 33
	SE (d)	1.7	3.8
Tributary Kelt Timing[c]	*N*	30	6
	Dates	16 May - 21 Jun	29 May - 23 Jun
Kelt Emigration[d]	*N* [e]	28	3
	Dates	23 May - 25 Jun	30 May - 29 Jun
	Mean (d)	7.6	16.7
	Range (d)	1 - 16	9 - 31
	SE (d)	0.96	7.2
2009			
Spawning Period	*N* [a]	15	7
	Dates[b]	28 Apr - 15 Jun	13 May - 22 Jun
	Mean (d)	18.3	18.3
	Range (d)	3 - 35	3 - 40
	SE (d)	2.5	5.4
Tributary Kelt Timing[c]	*N*	15	7
	Dates	12 May - 15 Jun	21 May - 22 Jun
Kelt Emigration[d]	*N* [e]	15	4
	Dates	12 May - 16 Jun	21 May - 20 Jun
	Mean (d)	7.0	22.0
	Range (d)	1 - 21	12 - 26
	SE (d)	1.7	3.3

[a] Radio-tagged steelhead that spawned and died in Crooked (2008 N=7; 2009 N=5) and Nikolai (2008 N=2; 2009 N=3) creeks were omitted from the analysis.
[b] Dates of first and last radio-tagged steelhead to enter and exit spawning tributaries.
[c] Timing of the first and last kelt egressing spawning tributaries.
[d] Dates and duration of kelts from tributaries emigrating the Kasilof River and Tustumena Lake after spawning.
[e] Kelt emigration could not be determined for two radio-tagged steelhead from Crooked Creek during 2008 and six from Tustumena Lake tributaries (2008 N=3; 2009 N=3) because they either died in the lake or remained in freshwater beyond the last tracking event.

While no radio-tagged steelhead was assigned a "Harvested" fate (Table 4), radio-tagged fish were often found at locations where fisheries were occurring (Figures 6-9). During April each year, several radio-tagged steelhead staged for spawning near the mouth of Crooked Creek and the outlet of Tustumena Lake, both of which are popular locations for shore-based sport fishing for steelhead (Figure 6 and 7). After spawning, radio-tagged kelts emigrated from the Kasilof River drainage and passed through areas used for the boat- and land-based Chinook salmon sport fishery during May and June each year. The kelt emigration also overlapped with that of the personal-use gillnet fishery conducted at the mouth of the Kasilof River in June (Figures 7 and 8). In the fall of both years (October and November), several radio-tagged steelhead were also located within the area used for Federal subsistence coho salmon fishing (Figure 9).

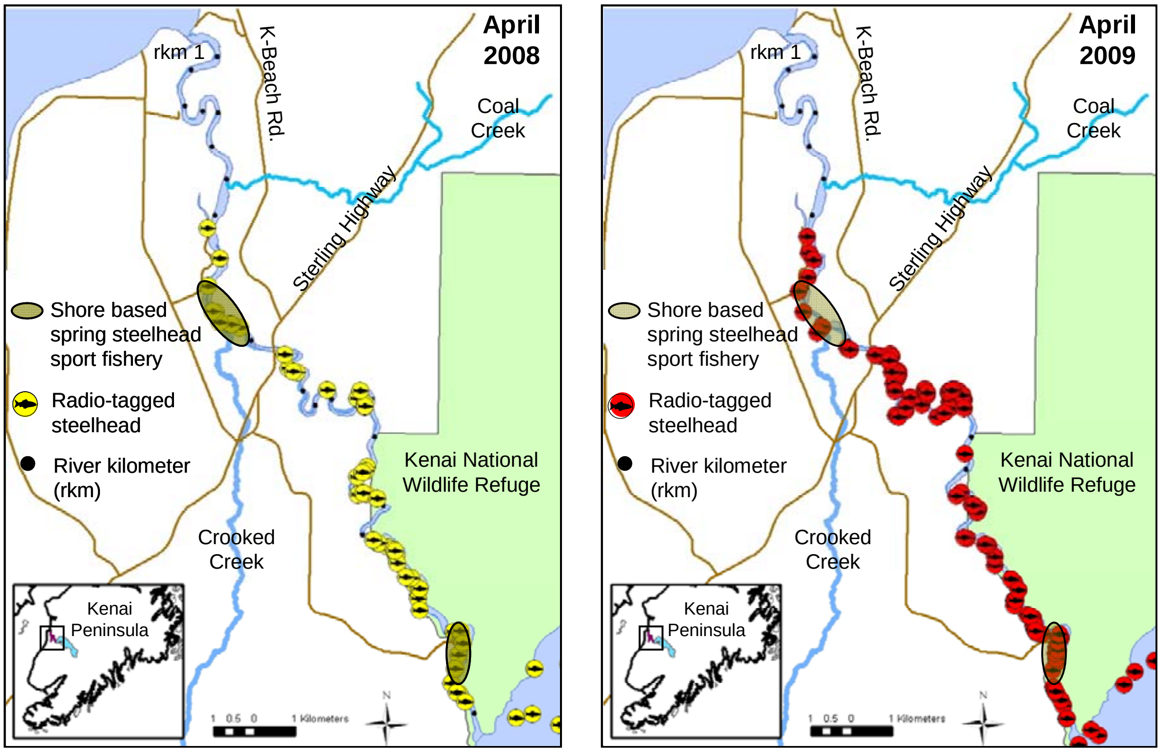

FIGURE 6.—Locations of radio-tagged steelhead during mobile tracking events conducted in the lower Kasilof River watershed during April, 2008 and 2009. Shaded areas represent the general locations of sport fishing. All active detections of radio-tagged steelhead are shown.

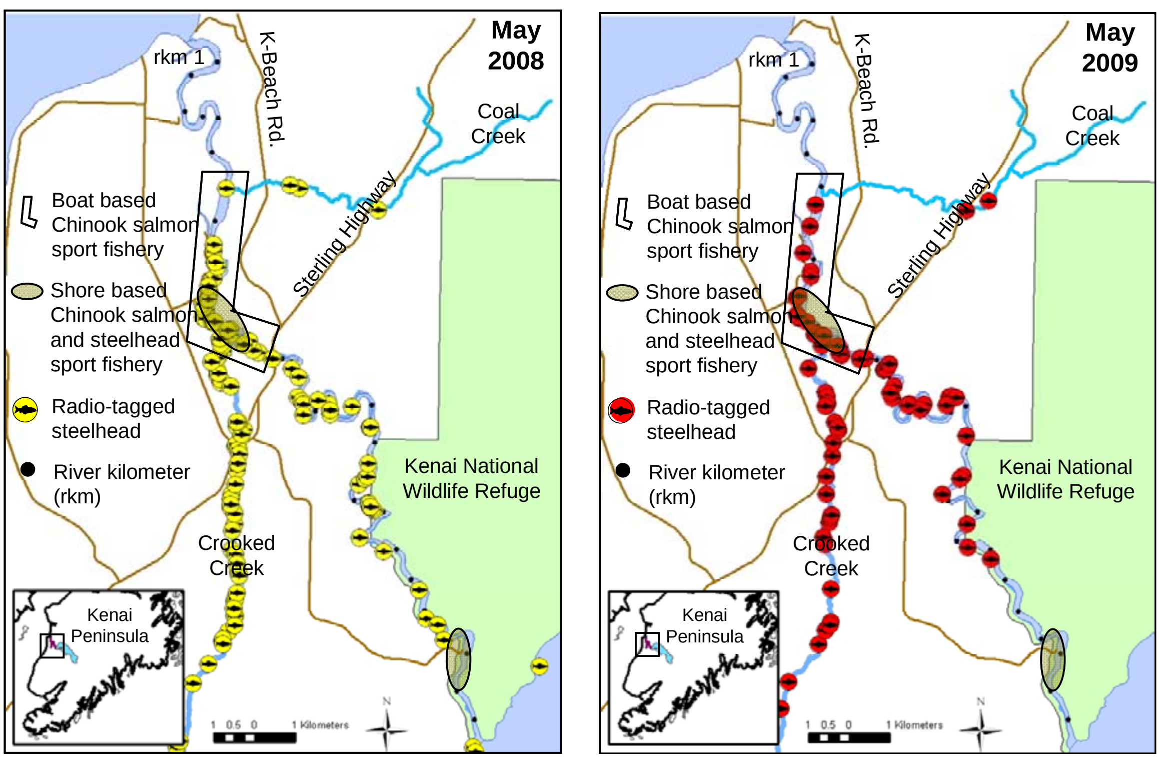

FIGURE 7.—Locations of radio-tagged steelhead during mobile tracking events conducted in the lower Kasilof River watershed during May, 2008 and 2009. Shaded areas represent the general locations of sport fishing. All active detections of radio-tagged steelhead are shown.

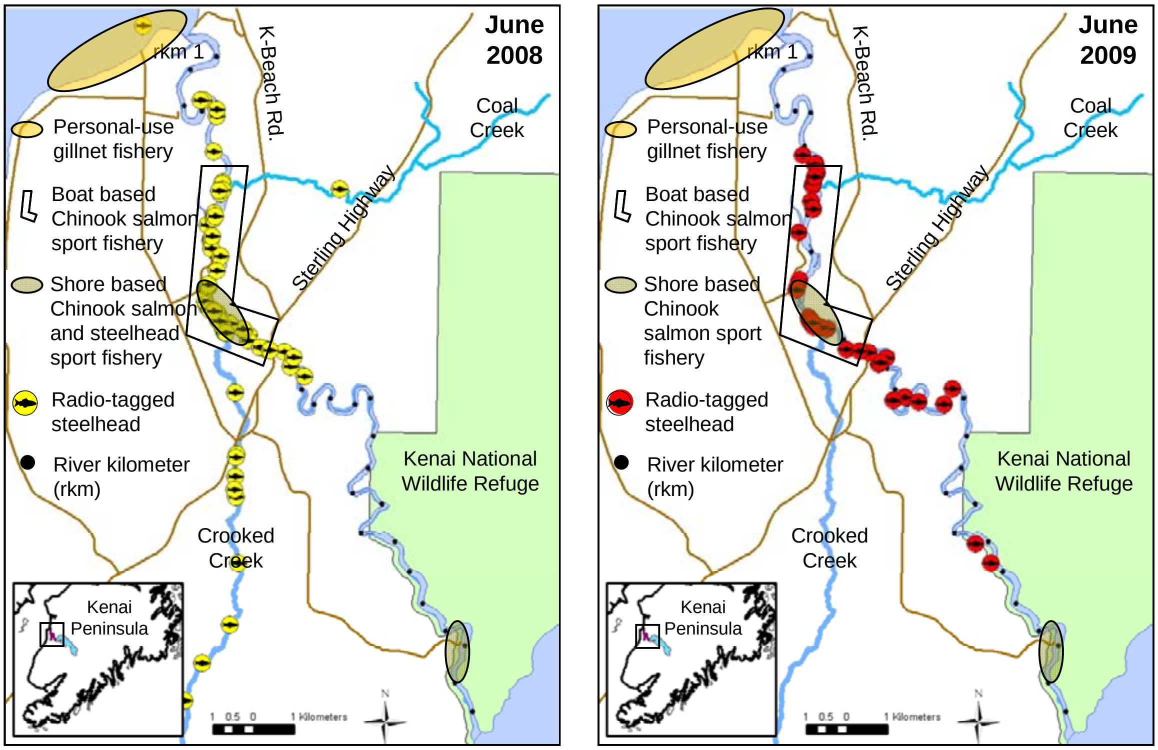

FIGURE 8.—Locations of radio-tagged steelhead during mobile tracking events in the lower Kasilof River watershed during June, 2008 and 2009. Shaded areas represent the general locations of sport and personal-use fishing. All active detections of radio-tagged steelhead are shown.

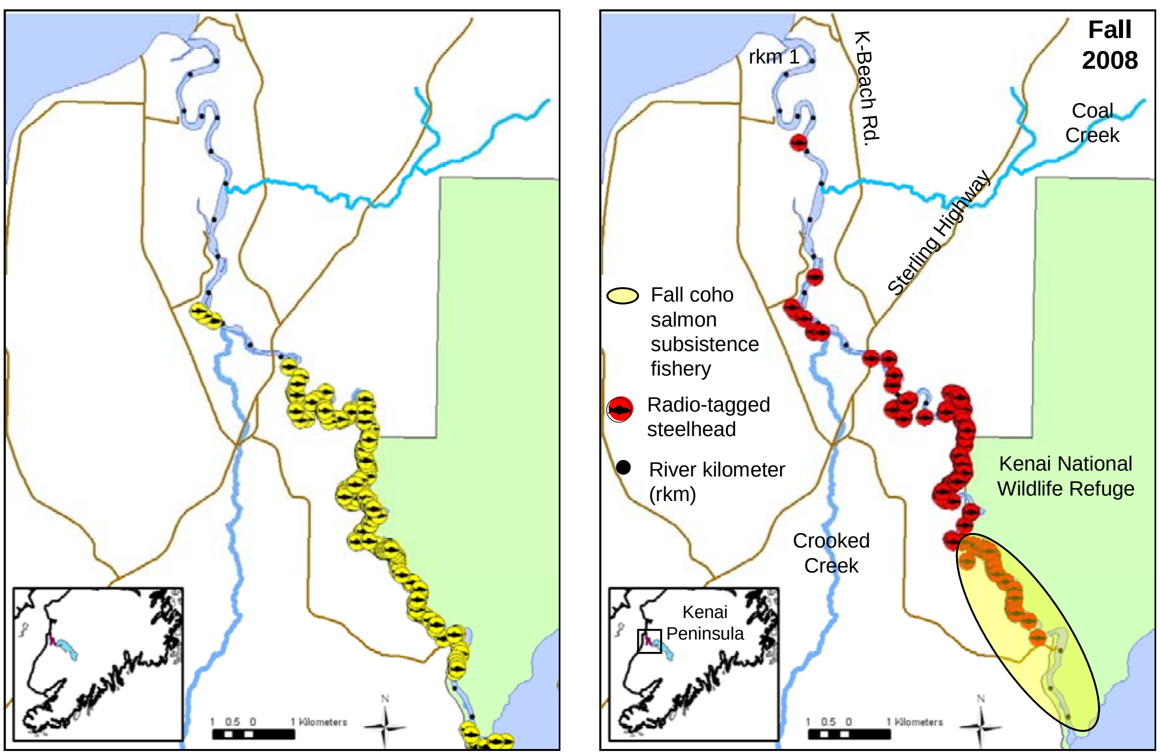

FIGURE 9.—Locations of radio-tagged steelhead during mobile tracking events in the lower Kasilof River watershed during October and November, 2007 and 2008. Shaded areas represent the location of the Federal subsistence fishery in the upper Kasilof River. All active detections of radio-tagged steelhead in the Kasilof River during the fall period are represented in each map.

Discussion

Based on the observed spawning distribution of radio-tagged steelhead tagged during October 2007, we were concerned that Crooked Creek spawners, which accounted for 69% of steelhead tracked to spawning locations in 2008, may have been over-represented and the lake tributary spawners, which accounted for 15% of steelhead tracked to spawning locations, may have been under-represented (Table 4). In particular, we expected a higher percentage of radio-tagged fish in Nikolai Creek, which accounted for only 11% of steelhead tracked to spawning locations based on our weir spawning escapement estimates for both Nikolai and Crooked creeks (Gates and Boersma 2009). These results suggested that our tagged steelhead population was likely not representative of the actual steelhead population returning to the Kasilof River watershed. Therefore, we suspected that differences in run timing among individual spawning populations in 2007 led to some components being less available or unavailable to our tagging program. To increase our chances of better representing all spawning groups in our 2008 tagging program, we initiated radio tagging operations about one month earlier in 2008 (2007, 4 October; 2008, 9 September), which also allowed us to deploy radio transmitters over a longer time period (2007, 13 d; 2008, 33 d). This resulted in a lower percentage of radio-tagged steelhead in Crooked Creek (44%) and a higher percentage in Nikolai Creek (18%) during 2009. Unexpectedly, we also found a much greater percentage of radio-tagged fish spawning in the mainstem Kasilof River during 2009 (27%) than in 2008 (11%). Additionally, some spawning components were not represented in both the 2007 and 2008 tagging populations. Tagged fish were found spawning in Indian Creek only during 2008 and in Shantatalik Creek only during 2009. This suggests that our capture and tagging efforts were probably not intensive enough to adequately represent all spawning groups, but regardless, we did identify four previously unreported spawning populations (Coal, Indian, and Shantatalik creeks as well as mainstem Kasilof River).

Another notable difference between 2007 and 2008 tagging results was an increase in the percentage of radio-tagged steelhead that backed out of the watershed (2007, 8%; 2008, 29%) (Table 4). Most of the steelhead classified as "Back-outs" were captured and tagged during September 2008 (Table 5). One possible explanation for this observation is that steelhead netted and tagged in September were not fully acclimated to freshwater and were more susceptible to handling than fish captured in October. This coincides with our observations of greater numbers of steelhead handled at the time of capture in September that exhibited descaling and open wounds versus fish captured in October. However, this hypothesis is inconsistent with anecdotal reports of steelhead routinely moving between freshwater and saltwater in coastal streams, and high survival rates reported for steelhead frequently handled, transported, and held for lengthy periods during a Vancouver Island, British Columbia, study (Hooten 1987). If steelhead can be stressed to lethal levels during these periods or to levels that prevent them from spawning, fish entering freshwater during September and presumably August could be significantly impacted during fall fisheries. More consequential, if differential migratory timing occurs for unique spawning groups during the freshwater immigration, individual populations consisting of low numbers and earlier run timing may be affected at higher rates. Differential run timing among distinct spawning groups of fall run steelhead within the same coastal watershed does not appear to have been documented, but commonly occurs in Pacific salmon populations throughout Alaska (e.g. Palmer et al. 2008; Anderson 2009; Seeb et al. 2009; Gates et al. 2009).

While handling induced behavior could explain why some tagged steelhead left the system, we also think some of these fish had entered the Kasilof River to take advantage of available food resources (i.e. Chinook and coho salmon spawn) before returning to saltwater to ascend other watersheds or simply reside in the ocean environment for another winter. The two steelhead tagged in the Kasilof River and later relocated near the mouths of Stariski Creek and the Anchor River seem to support this view. We also think that steelhead entering the Kasilof River during the fall continue to feed while they are in the river system prior to spawning the next spring, although it is generally thought that steelhead do not commonly feed after entering freshwater (Shapovalov and Taft 1954; Barnhart 1986). However, this behavior does not explain why steelhead are routinely caught by anglers in freshwater and, in fact, we feel that fall run steelhead need to feed in order to survive up to nine months of freshwater residence. Adult steelhead entering freshwater probably revert to their juvenile behavior of opportunistically feeding (Barnhart 1986) on a variety of prey (Merz 2002). This idea is supported in findings by Kesner and Barnhart (1972), who found eight different food materials, including salmon eggs, fish, and aquatic insects, in the stomachs of fall-run steelhead captured in the Klamath River watershed during 1967 and 1968. Hallock et al. (1961) also observed steelhead returning to the Sacramento River feeding on Chinook salmon eggs during the fall and winter months and reported a continual feeding behavior until the time of spawning. This behavior is also supported by our findings of radio-tagged steelhead distributed in locations containing aggregations of spawning salmon. Similar opportunistic or plastic behaviors, although for different reasons, have been observed for summer-run steelhead migrating through the lower Columbia River. High et al. (2006) reported that summer-run steelhead entering the Columbia River often use lower tributaries as staging areas for 1 h to 237 d while waiting for mainstem river waters to cool before migrating to spawning areas farther upriver.

The timing of the spawning period and kelt emigration was similar between 2008 and 2009 for radio-tagged steelhead spawning in Crooked Creek and Tustumena Lake tributaries (Figure 5, Table 8). The resulting small numbers of steelhead located in Tustumena Lake tributaries made it necessary to combine these spawning groups for estimating spawning and kelt emigration timing. While the combined sample size was still small, we feel that our estimates provide a good idea of timing during both years. Radio-tagged steelhead spawning in Coal Creek and the mainstem Kasilof River were omitted from the analysis because specific entry and/or exit times could not be determined for these fish; there was no fixed receiver station located near the mouth of Coal Creek and nearly all of the mainstem Kasilof River spawners overwintered in the Kasilof River making it difficult to determine the commencement of spawning. The spawning periods and kelt emigrations for these two spawning groups would have relied exclusively on mobile tracking events which occurred weekly but could have varied by as much as 10 days.

Steelhead assigned “Dead/Expelled” fates accounted for 6% (N=5) of the radio-tagged fish during 2008 and 2009, down from the 18% observed in 2007 and 2008. None of these five fish were classified as spring mortalities unlike the 8% during 2008. All of these spring mortalities exhibited similar overwintering and migratory behavior as other radio-tagged fish that overwintered and spawned in the Kasilof River watershed with the exception that they emitted continuous mortality signals soon after migrating to the mouth of Crooked Creek. These mortalities are most likely associated with the spring sport fishery that occurs near the mouth of Crooked Creek. This level of hooking mortality is higher than the 5% reported from a two year study for the Keogh River in British Columbia (Hooten 1987) but less than the near 10% reported for summer-run steelhead in two California rivers (Taylor and Barnhart 1999). The distribution of radio-tagged fish in the lower Kasilof River during the spring of 2009 was similar to what was observed in 2008. This is a period when several of the radio-tagged steelhead staged for spawning near the mouth of Crooked Creek and numerous anglers are observed fishing near the mouth (Figure 6 and 7). Several anglers reported catching radio-tagged steelhead on more than one occasion in this fishery during 2008 but none in 2009. Nonetheless, we suspect some of our radio-tagged fish were caught during the 2009 sport fishery because the observed angler effort appeared to be similar to 2008.

Steelhead kelts emigrating from the Kasilof River are also caught in two additional fisheries. Our findings indicate a significant overlap in the timing of their emigration and the in-river Chinook salmon sport fishery and personal-use gillnet salmon fishery (Figure 7 and 8). The Department recorded a by-catch of 134 steelhead in 2008 and 111 steelhead in 2009 during the in-river Chinook salmon sport fishery that occurs from 16 May to 30 June below the Sterling Highway Bridge (Alaska Department of Fish and Game, unpublished data). Additionally, one radio-tagged steelhead reported as being caught, misidentified as a sockeye salmon, and subsequently harvested by a personal-use fisher near the mouth of the Kasilof River in 2009 was later delivered to the Service after another individual identified it as a steelhead. Other instances of radio-tagged steelhead being caught were reported by fishers during the 2008 personal-use gillnet fishery, although none of these were known to have been harvested. Mortality of steelhead associated with either of these fisheries is unknown, but regardless of the gear type, some degree of injury occurs to the fish (e.g. external wounds and scale loss), with the severity of the injury depending on the gear type and its operation (Suuronen 2005). Hooking mortality associated with the in-river Chinook salmon sport fishery might be expected to be similar to the 5% to 10% reported from studies of directed steelhead sport fisheries (Hooten 1987; Taylor and Barnhart 1999) with capture and handling mortality being much greater for steelhead caught in gillnets during the personal-use salmon fishery. We are not aware of any gillnet mortality studies conducted with steelhead, but studies on Pacific salmon have shown that gillnet mortality can be very high. For example, Thompson et al. (1971) reported an 80% mortality of sockeye salmon caught and unmeshed from gillnets with the greatest mortality occurring for fish escaping multifilament nets (Thompson and Hunter 1973). Similarly, the Canadian Department of Fisheries and Oceans (Coho Response Team 1998) estimated that 35% to 70% of coho salmon caught in gillnet fisheries died shortly after encountering their gear. More detailed reporting requirements for the personal-use fishery could provide important by-catch information at minimal cost and effort and because steelhead can easily be mistaken for other species, public outreach related to species identification should also be a priority in these mixed-stock fisheries.

The Federal subsistence dip net and fish wheel salmon fishery occurring in the mainstem Kasilof River from 16 June to 31October could also impact steelhead, particularly during the fall (Figure 9). Several radio-tagged steelhead were located within the bounds of this fishery above rkm 24 during October and November 2007 and 2008 (Figure 9). We suspect that some of these steelhead probably feed in this area during the fall and early winter prior to spawning as Palmer et al. (2008) and Gates et al. (2009) identified several radio-tagged coho salmon spawning in this section of river. Steelhead were also observed traveling through this section of river during the fall to overwintering areas in Tustumena Lake. Few people have participated in the Kasilof River dip net subsistence fishery, which began in 2007, and a fish wheel, although approved for operation, has not yet been installed. Even though Federal subsistence fishing regulations do not allow retention of steelhead or rainbow trout caught in dip nets after 15 August, and all steelhead and rainbow trout caught in the fish wheel must be released, some level of handling mortality could be associated with either capture technique. Species identification could also be an issue as most steelhead look similar to many bright coho salmon during this time of year. To date, no coho salmon have been reported as being harvested from the dip net fishery.

Conclusions

- Our radio telemetry studies of steelhead in the Kasilof River watershed, conducted between 2007 and 2009, identified four previously unknown spawning areas: Indian Creek, Coal Creek, Shantatalik Creek and the mainstem Kasilof River.

- Our findings also indicated that the estuary, river, outlet, lake and tributary regions are all important to steelhead during different times of the year for feeding, overwintering, spawning, and migration.

- We documented a substantial overlap between different stages of steelhead freshwater migration and the occurrence of several fisheries that could be sources of significant adult steelhead mortality.

- Information from this project will be useful in evaluating and, if needed, modifying existing management strategies and regulations affecting steelhead returning to the Kasilof River watershed.

Recommendations

Our recommendations for future work on steelhead within the Kasilof River drainage as it pertains to Federal subsistence fisheries includes:

- Monitor spawning populations periodically to ensure these populations are being sustained.

- Use methods developed by Bromaghin et al. (In review) for coho salmon to estimate abundance of mainstem and tributary spawners using existing information collected between 2007 and 2009.

- Improve public outreach and education on steelhead identification since steelhead can be easily mistaken for coho salmon in mixed-stock fisheries.

- Expand the genetic baseline of spawning groups and, if distinct groups are present, determine whether differences can be detected in mixed-stock samples with a reliable level of accuracy and if differential run timing exists among spawning groups as they enter the Kasilof River during the fall.

- If a fish wheel is installed in the Kasilof River, determine survival rates for steelhead and rainbow trout that are captured and released.

- Require more detailed reporting requirements for the personal-use fishery on by-catch of steelhead.

Acknowledgements

Special appreciation is extended to those who participated in field operations including Waylon Marler, Chad Whaley, Todd Anderson, Haley Ohms, and Bill Carter. Special thanks are also extended to Refuge pilots Rick Johnston and Rick Ernst, and Alaska West Air pilot Doug Brewer for flying the aerial surveys and Jeffrey Bromaghin for assisting with project design.

The U.S. Fish and Wildlife Service, Office of Subsistence Management provided funds for this project through the Fisheries Resource Monitoring Program, Project FIS 07-509 and FIS 08-503.

References

Anderson, J.L. 2009. Estimating the spawning distribution of Pacific salmon in the Matanuska River watershed, southcentral Alaska, 2008. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Number 2009-12, Anchorage, Alaska.

Bali, J. M. 1959. Scale analyses of steelhead, *Salmo gairdnerii gairdnerii* Richardson, from various coastal watersheds of Oregon. Master's thesis. Oregon State College, Corvallis.

Barnhart, R.A. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) – steelhead. U.S. Fish and Wildlife Service, Biological Report 82 (11.60). U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

Begich, R. N. 1997. Assessment of the 1995 return of steelhead to the Karluk River, Alaska. Alaska Department of Fish and Game, Fishery Data Series Number 97-6, Anchorage, Alaska.

Bromaghin, J.F., K.S. Gates, and D.E. Palmer. In review. A likelihood framework for joint estimation of salmon abundance and migratory timing using telemetric mark-recapture. North American Journal of Fisheries Management.

Burgner, R. L., J. T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and origins of steelhead (*Oncorhynchus mykiss*) in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission Bulletin 51, Vancouver, British Columbia, Canada.

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.

Chapman, D. W. 1958. Studies on the life history of Alsea River steelhead. Journal of Wildlife Management 22(2):123-134.

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.

Coho Response Team. 1998. Coho salmon final report. Fisheries and Oceans Canada, Pacific Region, Vancouver, British Columbia, Canada

Gamblin, M., L. E. Marsh, P. Berkhahn, and S. Sonnichsen. 2004. Area management report for the recreational fisheries of the northern Kenai Peninsula, 2000-2001. Alaska Department of Fish and Game, Fishery Management Report Number 04-04, Soldotna, Alaska.

Gates, K. S., and D. E. Palmer. 2006a. Abundance and run timing of adult steelhead trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2005. US Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2006-5, Kenai, Alaska.

Gates, K. S., and D. E. Palmer. 2006b. 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.

Gates, K. S., and D. E. Palmer. 2008. Abundance and run timing of adult steelhead trout in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2007. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2008-3, Kenai, Alaska.

Gates, K. S., and J. K. Boersma. 2009. Abundance and run timing of adult steelhead in Crooked and Nikolai Creeks, Kenai Peninsula, Alaska, 2008. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2009-2, Soldotna, Alaska.

Gates, K.S. 2009. Spawning and seasonal distribution of adult steelhead in the Kasilof River watershed, Alaska, 2007 and 2008. Alaska Fisheries Data Series Number 2009-11, Kenai, Alaska.

Gates, K.S., D.E. Palmer, and J.F. Bromaghin. 2009. Run timing, abundance, and distribution of adult coho salmon in the Kasilof River watershed, Alaska, 2008. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2009-14, Soldotna, Alaska.

Hallock, R.J., VW.F. William, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmon gairdnerii gairdnerii) in the Sacramento River system. Fish Bulletin Number114, UC San Diego: Scripps Institution of Oceanography Library.

High, B., C.A. Perry, and D.H. Bennett. 2006. Temporary staging of Columbia River summer steelhead in coolwater areas and its effect on migration rates. Transactions of the American Fisheries Society 135:519-528.

Hooten, R.S. 1987. Catch and release as a management strategy for steelhead in British Columbia. Pages 143-156 *in* R.A. Barnhart and T.D. Roelofs, editors. Catch-and Release Fishing: A decade of experience, symposium proceedings. Humboldt State University, Arcata, California.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series Number 95-24, Anchorage, Alaska.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series Number 96-32, Anchorage, Alaska.

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.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2007. Participation, catch, and harvest in Alaska sport fisheries during 2004. Alaska Department of Fish and Game, Fishery Data Series Number 07-40, Anchorage, Alaska.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009a. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2005. Alaska Department of Fish and Game, Fishery Data Series Number 09-47, Anchorage, Alaska.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2009b. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2006. Alaska Department of Fish and Game, Fishery Data Series Number 09-54, Anchorage, Alaska.

Johnson, J., and M. Daigneault. 2008. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, Effective June 2, 2008. Alaska Department of Fish and Game, Special Publication Number 08-05, Anchorage, Alaska.

Jones, D.E. 1974. The study of cutthroat-steelhead in Alaska. Alaska Department of Fish and Game, Annual Performance Report Number AFS-42.

Kesner, W.D. and R.A. Barnhart. 1972. Characteristics of the fall-run steelhead trout (Salmo gairdneri gairdneri) of the Klamath River system with emphasis on the half-pounder. California Fish and Game, 58(3): 204-220.

Larson, L. L., and D. T. Balland. 1989. Statistics for selected sport fisheries on the lower Kenai Peninsula, Alaska, during 1988 with the emphasis on Dolly Varden char. Alaska Department of Fish and Game, Fishery Data Series Number 101, Juneau, Alaska.

Lindsay, R. B., K. R. Kenaston, and R. K. Schroeder. 1991. Steelhead production factors. Oregon Department of Fish and Wildlife, Fish Research Project F-120-R, Annual Progress Report, Portland, Oregon.

Meigs, R.C. and C.P. Pautzke. 1941. Additional studies on the life history of the Pudget Sound steelhead (*Salmo gairdneri*). State of Washington Department of Game, Biological Bulletin 5: 13

Merz, J.E. 2002. Seasonal feeding habits, growth, and movement of steelhead trout in the lower Moelumne River, California. California Fish and Game 88(3):95-111.

Mills, M. J. 1994. Harvest, Catch, and Participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, 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., K. S. Gates, and J. F. Bromaghin. 2008. Run timing, abundance, and distribution of adult coho salmon in the Kasilof River watershed, Alaska, 2007. U.S. Fish and Wildlife Service, Alaska Fisheries Data Series Report Number 2008-19, Soldotna, Alaska.

Robards, M.D. and T.P. Quinn. 2002. The migratory timing of adult summer-run steelhead in the Columbia River over six decades of environmental change. Transactions of the American Fisheries Society 131:523-536.

Sanders, G. 1985. Summary of age, sex, run timing, and length-weight characteristics of Alaska steelhead. Pages 29-49 *in* Alaska Department of Fish and Game, Alaska Steelhead Workshop 1985, unpublished manuscript, 134 p. (Available from Alaska Resources Library and Information Services, ARLIS Room 111, Library Building, 3211 Providence Drive, Anchorage, Alaska 99508).

Seeb, L.W., N.A. DeCovich, A.W. Barclay, C.T. Smith, and W.D. Templin. 2009. Timing and origin of Chinook salmon stocks in the Copper River and adjacent ocean fisheries using DNA markers. Alaska Department of Fish and Game, Fishery Data Series Number 09-58, Anchorage, Alaska.

Shapovalov, L., and A. C. Taft. 1954. The life histories of steelhead rainbow trout (Salmo gairdnerii gairdnerii) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game, Fish Bulletin 98.

Smith, S.B. 1969. Reproductive isolation in summer and winter races of steelhead. Pages 21-38 *in* Northcote, T.C., editor. Symposium of salmon and trout streams, 1968 February 22-24, Vancouver, British Columbia. University of British Columbia, Vancouver, British Columbia.

Summerfelt, R. C. and L. S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213–272 *in* C.B. Schreck and P.B. Moyle, editors. Methods for Fish Biology. American Fisheries Society, Bethesda, Maryland.

Suuronen, P. 2005. Mortality of fish escaping trawl gears. Finnish Game and Fisheries Research Institute, Food and Agriculture Organization of the United Nations, Fisheries Technical Paper 478, Helsinki, Finland.

Taylor, G. and R.A. Barnhart. 1999. Mortality of angler caught and released summer steelhead. California Cooperative Fishery Research Unit and Humboldt State University Foundation, Contract Number FG 5018 IF, California Department of Fish and Game, Steelhead Trout Catch Report-Restoration Card.

Thompson, R.B., C.J. Hunter, and B.G. Pattern. 1971. Studies of live and dead salmon that unmesh from gillnets. International North Pacific Fisheries Commission, Annual Report 1969, pages 108-112.

Thompson, R.B. and C.J. Hunter. 1973. Viability of adult sockeye salmon that disentangle from gillnets. International North Pacific Fisheries Commission, Annual Report 1971, pages 107-109.

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.

Wallis, J. and D.T. Balland. 1982. Anchor River Steelhead Study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Volume 23, Anadromous Fish Studies-48-2, Juneau, Alaska.

Wallis, J. and D.T. Balland. 1983. Anchor River Steelhead Study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, F-9-16 (25) Anadromous Fish Studies-48-3, Juneau, Alaska.

Wallis, J. and D.T. Balland. 1984. Anchor River Steelhead Study. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, F-9-16 (25) Anadromous Fish Studies-48, Juneau, 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.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (Salmo gairdneri) along the Pacific Coast of North America. Journal of Fisheries Research Board Canada, Volume 23(3): 365-393.

APPENDIX 1. —Summary of steelhead radio-tagged in the Kasilof River during 2007.

Fish Number	Sex	Mid-eye to Fork Length (mm)	Tagging Date	Final Fate	Overwintering Regions
0323	M	730	4-Oct	Spawner (Mainstem)	Outlet
3423	M	725	4-Oct	Spawner (Crooked Creek)	River
3543	M	700	4-Oct	Dead (Angler Mortality)	River
3863	M	690	4-Oct	Dead (Natural/Expelled Tag)	–
0324	M	535	4-Oct	Dead (Angler Mortality)	Outlet, River
3424	F	655	4-Oct	Dead (Angler Mortality)	River
3544	F	610	4-Oct	Back Out	–
3864	F	780	4-Oct	Dead (Natural/Expelled Tag)	–
0325	F	655	4-Oct	Spawner (Crooked Creek)	Outlet, River, Lake
3425	M	670	4-Oct	Spawner (Crooked Creek)	Outlet, Lake
3545	F	645	5-Oct	Spawner (Mainstem)	Outlet, Lake
3865	F	640	5-Oct	Spawner (Crooked Creek)	Lake
0326	F	620	5-Oct	Spawner (Crooked Creek)	Outlet, Lake
3426	F	540	5-Oct	Spawner (Crooked Creek)	Outlet, Lake
3546	F	625	5-Oct	Non-Spawner	Outlet, River, Lake
3866	M	560	5-Oct	Back Out	–
0327	F	680	5-Oct	Dead (Natural/Expelled Tag)	–
3427	M	700	5-Oct	Spawner (Mainstem)	Outlet, River
3547	F	565	5-Oct	Back Out	–
3867	F	725	5-Oct	Spawner (Crooked Creek)	Outlet, River
0328	F	660	9-Oct	Spawner (Crooked Creek)	Lake
3428	F	640	9-Oct	Back Out	–
3548	M	600	9-Oct	Spawner (Nikolai Creek)	Outlet, Lake
3868	F	630	9-Oct	Spawner (Crooked Creek)	Outlet, River
0329	M	565	9-Oct	Spawner (Nikolai Creek)	Lake
3429	M	575	9-Oct	Spawner (Crooked Creek)	Outlet, Lake
3549	F	585	9-Oct	Non-Spawner	Lake
3869	M	660	9-Oct	Spawner (Crooked Creek)	Outlet, Lake
3210	M	700	9-Oct	Spawner (Crooked Creek)	Outlet, Lake
3430	F	685	9-Oct	Spawner (Crooked Creek)	Outlet
3550	F	695	10-Oct	Dead (Natural/Expelled Tag)	–
3870	M	565	10-Oct	Spawner (Crooked Creek)	Outlet, River, Lake
3211	M	645	10-Oct	Non-Spawner	Lake
3431	M	715	10-Oct	Spawner (Nikolai Creek)	Lake
3551	M	785	10-Oct	Spawner (Crooked Creek)	Outlet, River
3871	M	705	10-Oct	Spawner (Nikolai Creek)	Outlet, Lake
3212	M	625	10-Oct	Spawner (Crooked Creek)	Outlet, Lake
3432	F	605	10-Oct	Spawner (Crooked Creek)	River
3552	F	680	10-Oct	Spawner (Crooked Creek)	Lake
3213	F	705	11-Oct	Dead (Natural/Expelled Tag)	–
3433	F	560	11-Oct	Back Out	–
3553	M	690	11-Oct	Back Out	–
3873	F	610	12-Oct	Dead (Angler Mortality)	River
3214	M	630	12-Oct	Spawner (Crooked Creek)	Outlet, River, Lake
3434	M	580	12-Oct	Non-Spawner	Outlet
3554	M	520	12-Oct	Spawner (Coal Creek)	Outlet, River

-continued-

APPENDIX 1. —(Page 2 of 2)

Fish Number	Sex	MEF Length	Tagging Date	Final Fate	Overwintering Regions
3874	F	640	12-Oct	Spawner (Mainstem)	River
3215	F	665	12-Oct	Spawner (Mainstem)	River
3435	M	635	12-Oct	Spawner (Crooked Creek)	Outlet, Lake
3555	M	720	12-Oct	Spawner (Crooked Creek)	River
3875	F	645	12-Oct	Non-Spawner	Outlet, River
3216	F	650	12-Oct	Spawner (Indian Creek)	Outlet, Lake
3436	F	670	12-Oct	Spawner (Coal Creek)	Outlet, Lake
3556	F	700	12-Oct	Spawner (Crooked Creek)	Lake
3876	F	690	12-Oct	Dead (Natural/Expelled Tag)	–
3217	F	695	15-Oct	Dead (Natural/Expelled Tag)	–
3437	M	675	15-Oct	Spawner (Crooked Creek)	Lake
3557	F	645	15-Oct	Spawner (Nikolai Creek)	Outlet, River, Lake
3877	F	710	15-Oct	Spawner (Crooked Creek)	Lake
3218	F	675	15-Oct	Dead (Angler Mortality)	Outlet, River
3438	M	510	15-Oct	Spawner (Indian Creek)	Outlet, Lake
3558	M	570	15-Oct	Spawner (Crooked Creek)	Lake
3878	M	670	15-Oct	Spawner (Nikolai Creek)	Lake
3219	F	620	15-Oct	Spawner (Crooked Creek)	Outlet, River
3439	F	685	15-Oct	Spawner (Crooked Creek)	Outlet, River, Lake
3559	M	550	15-Oct	Spawner (Crooked Creek)	Outlet, River
3879	F	590	15-Oct	Spawner (Coal Creek)	Lake
3220	F	670	15-Oct	Dead (Angler Mortality)	Outlet, Lake
3440	F	640	15-Oct	Spawner (Mainstem)	Outlet, River
3560	M	575	15-Oct	Spawner (Crooked Creek)	Lake
3880	M	605	15-Oct	Spawner (Crooked Creek)	Outlet, River
3221	M	565	15-Oct	Spawner (Crooked Creek)	River
3441	F	650	15-Oct	Spawner (Crooked Creek)	River
3561	M	555	15-Oct	Spawner (Crooked Creek)	Outlet, Lake
3881	F	610	15-Oct	Dead (Natural/Expelled Tag)	–
3222	M	705	16-Oct	Spawner (Crooked Creek)	Outlet, Lake
3442	F	710	16-Oct	Spawner (Crooked Creek)	Outlet, River
3562	M	695	16-Oct	Spawner (Crooked Creek)	Lake
3882	M	540	16-Oct	Spawner (Crooked Creek)	Lake

APPENDIX 2. —Summary of steelhead radio-tagged in the Kasilof River during 2008.

Fish Number	Sex	Mid-eye to Fork Length (mm)	Tagging Date	Final Fate	Overwintering Regions
3803	F	740	9-Sep	Back Out	—
3223	F	620	10-Sep	Back Out	—
3443	F	670	10-Sep	Back Out	—
3563	F	705	10-Sep	Non-Spawner	Lake
3804	F	750	12-Sep	Back Out	—
3224	F	640	12-Sep	Back Out	—
3444	M	505	12-Sep	Spawner (Mainstem)	Outlet, Lake
3564	F	685	12-Sep	Back Out	—
3806	F	625	12-Sep	Non-Spawner	River
3225	F	665	12-Sep	Back Out	—
3445	F	640	12-Sep	Back Out	—
3565	F	525	12-Sep	Spawner (Mainstem)	River
3805	F	665	12-Sep	Back Out	—
3226	F	720	14-Sep	Back Out	—
3446	F	645	14-Sep	Back Out	—
3566	F	610	16-Sep	Back Out	—
3807	F	615	16-Sep	Spawner (Nikolai Creek)	Lake
3227	F	700	16-Sep	Back Out	—
3447	F	635	16-Sep	Spawner (Shantatalik Creek)	Lake
3567	F	680	24-Sep	Spawner (Nikolai Creek)	Lake
3228	F	625	24-Sep	Dead (Natural/Expelled Tag)	—
3448	F	675	24-Sep	Spawner (Crooked Creek)	River, Estuary
3568	F	740	24-Sep	Back Out	—
3808	F	740	24-Sep	Spawner (Crooked Creek)	River
3229	F	675	24-Sep	Non-Spawner	Lake
3449	M	705	24-Sep	Spawner (Nikolai Creek)	Lake
3569	F	680	25-Sep	Back Out	—
3809	F	720	25-Sep	Spawner (Mainstem)	River
3230	F	650	25-Sep	Spawner (Coal Creek)	River, Estuary
3450	F	700	25-Sep	Back Out	—
3570	F	690	25-Sep	Spawner (Nikolai Creek)	River, Outlet
3810	F	670	25-Sep	Spawner (Mainstem)	River, Outlet, Lake
3231	F	775	25-Sep	Spawner (Nikolai Creek)	Lake
3451	M	715	25-Sep	Spawner (Crooked Creek)	River, Outlet
3571	M	730	28-Sep	Spawner (Nikolai Creek)	River, Outlet
3811	F	750	28-Sep	Spawner (Nikolai Creek)	Lake
3232	F	615	28-Sep	Spawner (Crooked Creek)	Outlet, Lake
3452	M	715	28-Sep	Spawner (Crooked Creek)	River, Outlet
3572	F	615	28-Sep	Spawner (Mainstem)	River
3812	F	640	28-Sep	Spawner (Mainstem)	River
3233	M	550	1-Oct	Spawner (Coal Creek)	River, Outlet, Lake
3453	F	660	1-Oct	Back Out	—
3573	F	720	1-Oct	Non-Spawner	Lake
3813	M	530	1-Oct	Spawner (Mainstem)	River
3234	M	490	1-Oct	Spawner (Mainstem)	River
3454	F	670	1-Oct	Dead (Natural/Expelled Tag)	—

-continued-

APPENDIX 2. —(Page 2 of 2)

Fish Number	Sex	Mid-eye to Fork Length (mm)	Tagging Date	Final Fate	Overwintering Regions
3574	F	680	1-Oct	Spawner (Mainstem)	Lake
3814	F	685	1-Oct	Back Out	—
3235	M	660	1-Oct	Back Out	—
3455	M	720	1-Oct	Spawner (Crooked Creek)	River, Outlet
3575	F	645	2-Oct	Spawner (Crooked Creek)	River, Outlet
3815	F	780	2-Oct	Spawner (Mainstem)	River, Outlet
3236	M	675	2-Oct	Spawner (Crooked Creek)	River, Outlet
3456	F	530	2-Oct	Back Out	—
3576	M	530	2-Oct	Back Out	—
3816	F	660	2-Oct	Spawner (Crooked Creek)	River
3237	M	540	2-Oct	Spawner (Coal Creek)	River
3457	F	660	5-Oct	Non-Spawner	Lake
3577	M	515	5-Oct	Spawner (Shantatalik Creek)	Lake
3817	M	660	5-Oct	Spawner (Nikolai Creek)	Lake
3238	F	660	5-Oct	Back Out	—
3458	F	670	5-Oct	Spawner (Crooked Creek)	River
3578	F	740	5-Oct	Dead (Natural/Expelled Tag)	—
3818	F	685	5-Oct	Spawner (Crooked Creek)	River, Outlet
3239	F	730	5-Oct	Spawner (Crooked Creek)	River
3459	M	640	5-Oct	Spawner (Crooked Creek)	River
3579	F	670	5-Oct	Spawner (Crooked Creek)	River
3819	F	750	7-Oct	Dead (Natural/Expelled Tag)	—
3240	M	685	7-Oct	Spawner (Crooked Creek)	River
3460	M	735	7-Oct	Spawner (Crooked Creek)	River
3580	F	680	7-Oct	Spawner (Crooked Creek)	Lake
3820	F	680	7-Oct	Dead (Natural/Expelled Tag)	—
3241	F	660	9-Oct	Spawner (Crooked Creek)	River
3461	M	730	9-Oct	Spawner (Mainstem)	River
3581	F	680	9-Oct	Non-Spawner	River, Outlet
3821	F	650	9-Oct	Spawner (Mainstem)	River, Estuary
3242	F	615	11-Oct	Spawner (Crooked Creek)	River
3462	F	680	11-Oct	Spawner (Crooked Creek)	River, Outlet
3582	F	715	11-Oct	Non-Spawner	Lake
3822	F	630	11-Oct	Back Out	—