Fishery Data Series No. 15-01

Seasonal Distribution and Migration of Rainbow Trout in the Gulkana River, 2010-2012

by

Corey J. Schwanke

January 2015

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

FISHERY DATA SERIES NO. 15-01

SEASONAL DISTRIBUTION AND MIGRATION OF RAINBOW TROUT IN THE GULKANA RIVER, 2010-2012

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ABSTRACT

Rainbow trout *Oncorhynchus mykiss* in the Gulkana River were radiotagged and tracked for approximately 2 years to describe seasonal distributions and migration patterns and help identify additional spawning areas. A total of 100 radio tags were surgically implanted into rainbow trout ≥ 420 mm FL throughout 152 river kilometers (rkm) in the fall of 2010. A total of 17 aerial tracking surveys were flown from 7 October 2010 through 27 June 2012. Initial and overall survival was lower than expected during this study and constrained the results. Major findings for this rainbow trout population were as follows: 1) these fish were highly migratory and typically traveled long distances (i.e., > 100 rkm) from overwintering to spawning areas; 2) overwintering and spawning areas were not widespread; and 3) two new significant spawning areas were confirmed, including one in the mainstem Gulkana River and one in a tributary of the West Fork Gulkana River drainage. Limited evidence was found for strong fidelity to summertime feeding areas or for the occurrence of skip spawning.

Key words: rainbow trout, *Oncorhynchus mykiss*, telemetry, Gulkana River, movement, migration, home range, overwintering areas, seasonal distribution, spawning areas.

INTRODUCTION

The Gulkana River drainage (Figures 1 and 2) supports the largest known fisheries for rainbow trout *Oncorhynchus mykiss*, Chinook salmon *O. tshawytscha*, and Arctic grayling *Thymallus arcticus* within the Upper Copper Upper Susitna Management Area (UCUSMA), accounting for as much as half of the angler effort annually since 1977 (Somerville 2013). Although species-specific estimates of effort are not available for the Gulkana River drainage, catch of rainbow trout has been estimated since 1990. Rainbow trout catch peaked in 1997 at over 8,000 fish and has since shown variability dropping to a low of < 2,000 fish in 2006. The latest estimate of catch was 2,604 rainbow trout in 2012 (Somerville 2013).

For many anglers, such as those residing in the Alaska Interior, the Gulkana River hosts the nearest and most accessible wild rainbow trout population. Most rainbow trout are caught in a section of the mainstem Gulkana River between the outlet of Paxson Lake and Sourdough Creek Campground (Figure 2). This approximately 75 rkm section of river is particularly popular because it lies within the portion of the Gulkana River designated as a National Wild River, is easily accessible, and is believed to contain the highest densities of mature-sized rainbow trout within the drainage.

Geographically, the rainbow trout population in the Gulkana River is the farthest north in North America. The summering locations in the Middle Fork Gulkana River drainage extend north to latitude 62.920° with a major spawning area extending north to latitude 62.940° (Fleming 2004).

Wild rainbow trout in the Gulkana River are managed under the Cook Inlet and Copper River Basin Rainbow/Steelhead Trout Management Policy (CICRRTMP; ADF&G 1987). The policy details specific management policies and recommended research objectives. The stated policies are as follows:

> Policy I: native rainbow trout populations will be managed to maintain historical size and age composition and stock levels; and
>
> Policy II: a diversity of sport fishing opportunities for wild and hatchery rainbow/steelhead trout will be provided through establishment of special management areas by regulation.

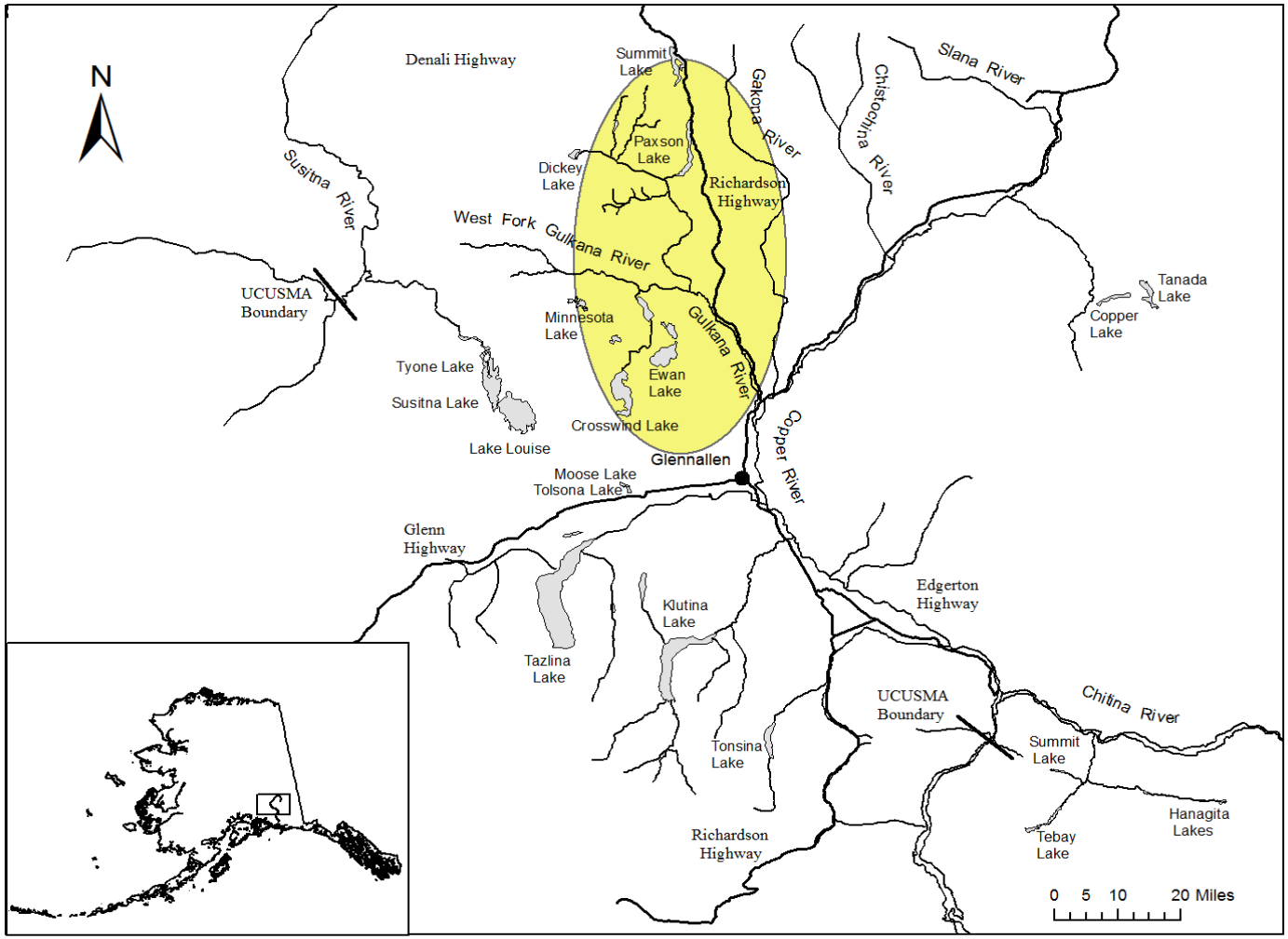

Figure 1.–Map of the Gulkana River (located in the upper center) within the Upper Copper Upper Susitna Management Area.

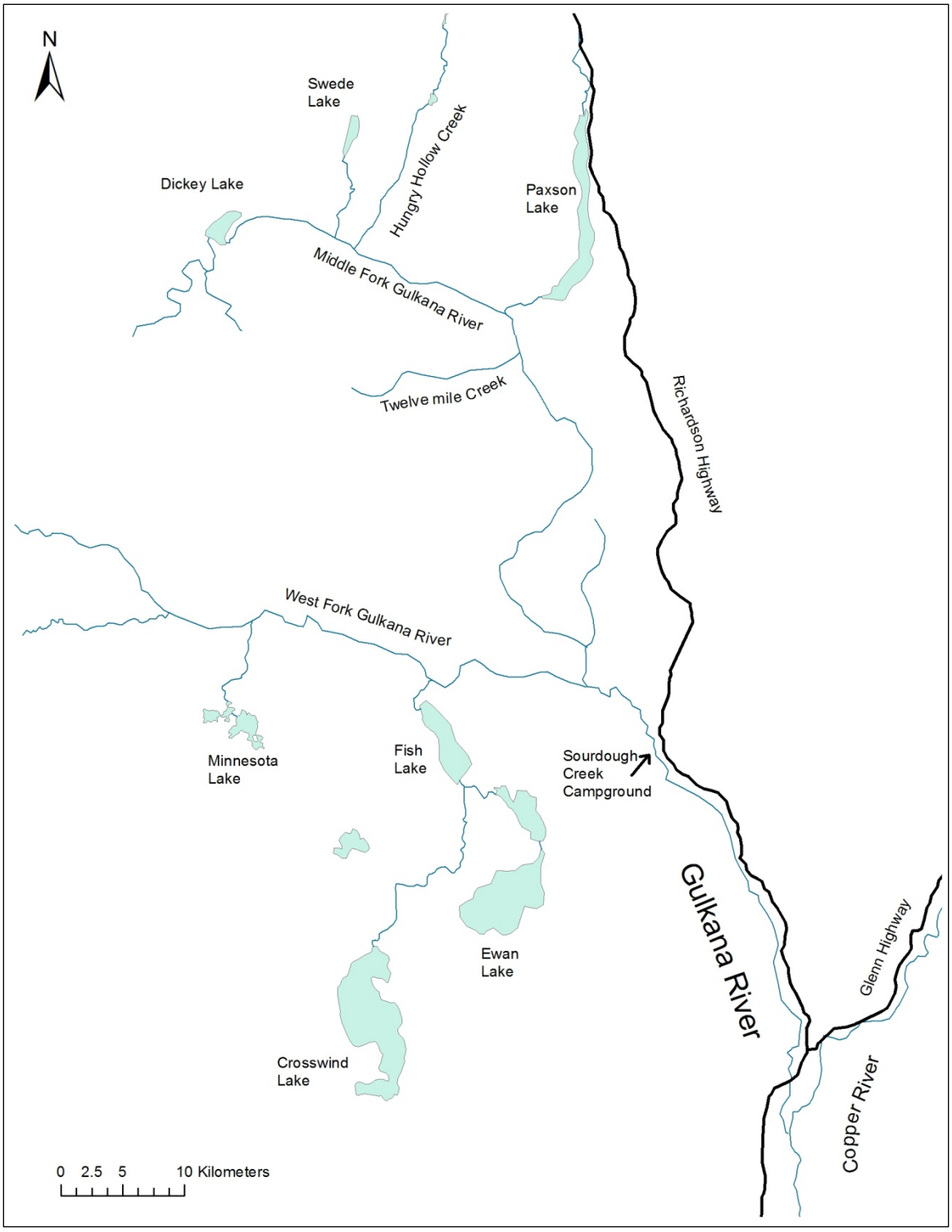

Figure 2.–Map of the study area within the Gulkana River.

The recommended research needs of the policy are as follows:

1. develop adequate methodologies to estimate rainbow trout abundance and fishing mortality;
2. develop an index of the relative abundance for rainbow/steelhead trout in selected waters;
3. examine spatial and seasonal distribution of rainbow trout in selected waters;
4. characterize size and age composition of rainbow/steelhead trout in selected waters;
5. develop information on the harvest of rainbow/steelhead trout; and
6. develop angler-preference information pertaining to the management of rainbow trout fisheries.

Since approval of this 1987 management policy, fishing regulations for rainbow trout, as well as steelhead, have become increasingly more restrictive because of perceptions that harvest levels were inconsistent with the goals of the management policy. For the Gulkana River drainage, these perceptions were not based on comprehensive rainbow trout stock assessments but rather on angler reports of low catches and low incidental catches of rainbow trout during research activities directed at other species (e.g., Arctic grayling). The chronology of the regulatory changes for rainbow trout/steelhead in the Gulkana River includes the following:

Prior to 1987: 10 fish per day, 10 in possession (only 2 of which could exceed 20 inches), bait and multiple hooks allowed;

1987: 2 rainbow trout per day and 2 in possession (only 1 fish over 20 inches);

1991: Catch-and-release in entire Gulkana River drainage; fishing gear restricted to the use of unbaited, artificial lures in all waters of the Gulkana River upstream of an ADF&G marker located 7.5 miles upstream of the West Fork Gulkana River (Figure 2). Below this location, anglers could use bait all year;

1997: Spawning closures (April 15 thru June 14) were instituted on a 3-mile section immediately downstream of Dickey Lake, and on all of Hungry Hollow Creek;

2000: Only unbaited, single-hook artificial lures were permitted in all flowing waters of the Gulkana River. Bait and multiple hooks were permitted downstream of the 7.5-mile marker to the Richardson Highway bridge between June 1 and July 19 to accommodate anglers targeting Chinook and sockeye salmon; and

2003: Twelvemile Creek was added to the listing of spawning area closures (April 15–June 14).

The Gulkana River has been the focus of several steelhead and rainbow trout studies. The most significant findings resulted from 1) a pair of radiotelemetry studies that identified spawning locations (Burger et al. 1983; Fleming 2004); 2) stock assessments conducted from 1996 to 2003 on two of the spawning areas identified at Dickey Lake and Hungry Hollow Creek (Fleming 1999, 2000 and 2004; Stark 1999; Wuttig et al. 2004); 3) a mark–recapture experiment that estimated abundance of rainbow trout ≥ 160 mm FL in the mainstem from the outlet of Paxson Lake to a point two miles downstream of Sourdough Creek Campground (Schwanke and Taras 2009); and 4) a compilation of directed and non-directed efforts to catch and sample rainbow

trout for length, weight, and age information, and to determine fish distributions (Fleming 1999, 2000; Stark 1999).

In the early 1980s, 24 steelhead radiotagged in the Copper River near Copperville led to the documentation of two spawning areas in the Middle Fork Gulkana River where both rainbow trout and steelhead were observed spawning together: Hungry Hollow Creek and a 5 rkm reach of river below the outlet of Dickey Lake (Burger et al. 1983). Fleming (2004) radiotagged 23 rainbow trout within the Gulkana River drainage, of which 12 survived to the spawning period. These fish reconfirmed the two previously known spawning areas, identified Twelvemile Creek as a spawning area for both steelhead and rainbow trout, and recognized an area in the mainstem Gulkana River as a suspected spawning location for rainbow trout.

Genetic and abundance information collected during the 2001–2003 studies on the Dickey Lake and Hungry Hollow Creek spawning stocks demonstrated that 1) the two spawning areas were genetically distinct for both rainbow trout and steelhead; 2) within a spawning area both steelhead and rainbow trout were genetically similar; and 3) the spawning stock of rainbow trout in each area was relatively small (e.g., approximately 250 fish; Wuttig et al. 2004).

In 2005, ADF&G estimated the abundance of rainbow trout in the mainstem Gulkana River from the outlet of Paxson Lake downstream approximately 80 rkm to a point a couple rkm below the Sourdough Creek Campground, including the lower 1.5 rkm of the Middle Fork Gulkana River (Schwanke and Taras 2009). The results of the stratified abundance estimate were 6,850 (95% CI = 4,850–8,885) trout 160–274 mm FL and 5,238 (95% CI = 3,888–6,588) trout ≥ 275 mm FL. Results of this study, along with an increase in positive angler reports and marked increases in catches identified by the Statewide Harvest Survey (Mills 1991-1994; Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004-2011, *in prep*; Romberg et al. *in prep*; and Walker et al. 2003) strongly supported the hypothesis that the rainbow trout population had recovered from overexploitation prior to 1991 (Figure 3).

Comparing the results of the 2005 abundance study and the known spawning abundances within the Middle Fork Gulkana River, a significant proportion of the total spawning population was unaccounted for. For example, approximately 1,300 fish of mature size (≥ 420 mm FL) were estimated to be in the river during the 2005 study (Schwanke and Taras 2009), but the two major spawning areas in the Middle Fork Gulkana River had approximately 500 estimated total spawners combined (Wuttig et al. 2004). This discrepancy was probably due to one or more undocumented spawning areas of rainbow trout in the mainstem or tributaries.

Information on spatial and seasonal distributions is important in determining whether unique subpopulations or stocks exist within the drainage and whether they are affected differently by harvest patterns or environmental factors. Telemetric studies have demonstrated that rainbow trout within a drainage can be composed of multiple spawning stocks; can exhibit extreme or little fidelity to spawning, feeding, and overwintering areas; and can exhibit either very small (< 5 rkm) or large (> 75 rkm) intra-annual movements to these areas (Adams 1996 and 1999; Fleming 2004; Lisac 1996; Meka et al. 2000; Nelle 2002; Palmer 1998; Schwanke and Hubert 2000; Schwanke and Thalhauser 2010; Wuttig et al. 2004).

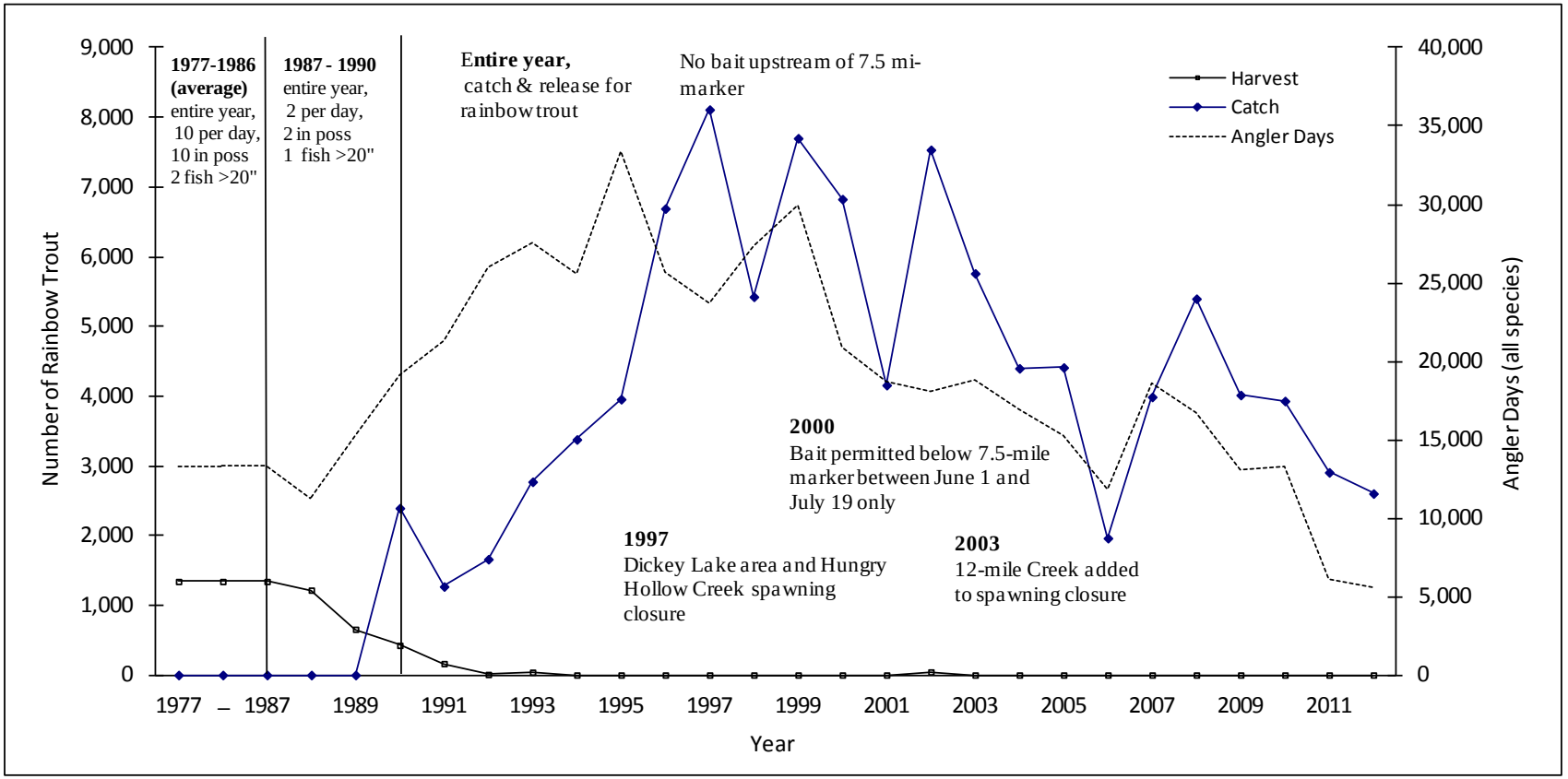

Figure 3.–Estimated number of rainbow trout harvested and caught, along with annual angling effort, in the Gulkana River drainage from 1977 to 2012. Vertical lines delineate major changes in regulation. Data is from Mills 1979-1994; Howe et al. 1995-1996, 2001a-d; Jennings et al. 2004-2011, *in prep*; Romberg et al. *in prep*; and Walker et al. 2003.

The goal of this telemetry study was to locate and document all putative major spawning and overwintering areas for the population of rainbow trout that inhabit the mainstem Gulkana River during summer, and to describe their seasonal movement patterns to overwintering, spawning, and summer feeding areas. The goals of this study and the research objectives specified below were consistent with policies and research needs identified in the CICRRTMP, with specific attention directed to research need #3.

OBJECTIVES

Project objectives for 2010–2012 were to

1. Describe the seasonal (summer 2010 to spring 2012) distribution patterns of mature-sized rainbow trout ≥420 mm FL in the Gulkana River implanted with radio transmitters during the summer feeding period when rainbow trout distributions are most widespread; and
2. Identify new potential spawning areas of rainbow trout that inhabit the Gulkana River during the summer feeding period when rainbow trout distributions are most widespread.

METHODS

STUDY AREA

The study area, as it related to sampling fish, included the mainstem Gulkana River from the Richardson Highway Bridge (about 6.5 rkm above the Copper River confluence) upstream to Paxson Lake (a total of 130.5 rkm). In addition, the lower 1 rkm of the Middle Fork Gulkana River was sampled, along with a 4.5 rkm section of the Upper Middle Fork Gulkana River (below the Swede Lake outlet creek).

The aerial tracking search area included the entire mainstem Gulkana River downstream of Paxson Lake, Twelvemile Creek, all of the Middle Fork Gulkana and its tributaries, and the entire West Fork Gulkana River including its tributaries. Paxson Lake was occasionally surveyed as well.

For the remainder of this report, river kilometers (rkm) will occasionally be used to describe river designations. The designations were obtained by using a highly accurate digitized map of the Gulkana River system, which was obtained from the National Hydrography Dataset (NHD) (NHD 2011). The confluence with the mouth of the Copper River was rkm 0 and progressed upstream to Paxson Lake outlet, which was rkm 137. Each tributary had its own distance, with the confluence being rkm 0.

STUDY DESIGN

During late summer 2010, 100 rainbow trout ≥ 420 mm FL (fork length) were initially captured and radiotagged in almost the entire length of the mainstem Gulkana River, as well as a 4.5 rkm section centered in a small area of the of the Middle Fork Gulkana River (rkm 25.5-30) where rainbow trout reside in the summertime. The preseason distribution of tags sought a compromise between deployment relative to densities of mature-sized fish and deployment throughout the drainage (Table 1). Information on density and catch rates from Schwanke and Taras (2009) was used, along with anecdotal angler reports.

For tag deployment, the river was divided into three primary sections: the Upper, Lower, and Middle forks. The upper fork extended between Sourdough Creek Campground (rkm 62.0) and

Paxson Lake (rkm 137.0) and included the lower 1 rkm of the Middle Fork Gulkana River. Seventy tags were allocated to the upper section where it was believed a large majority (i.e., ~90%) of rainbow trout resided. The lower section extended from Sourdough Creek to the Richardson Highway Bridge (rkm 6.5), where 20 tags were allocated and densities were believed to be far lower. The Middle Fork section was a 4.5 rkm reach of the Middle Fork Gulkana River at rkm 25.5-30.0. The majority of the Middle Fork Gulkana River is not suitable for rainbow trout, but this small reach of river is composed of good pool-riffle habitat for summer feeding. Although densities of fish in the Middle Fork section were probably lower than that of the mainstem above the West Fork Gulkana River confluence, an aggressive approach of 10 tags was warranted to ensure several fish survived to spawning.

Leftover tags from sampling efforts in the Middle Fork Gulkana River during early August were redeployed to the upper mainstem Gulkana River section during late August. Any tags left over at the conclusion of the August sampling were deployed at the confluence of the West Fork Gulkana River in late September. This area is known to be a significant overwintering area, and deploying any leftover tags here served to maximize our detection of undocumented spawning areas in the Gulkana River.

The density of rainbow trout in the West Fork Gulkana River was believed to be very low, based on surveys conducted by Fleming (2004). Little suitable habitat was observed by Fleming (2004), and only one fish was captured during a 6-day float trip covering approximately 40 rkm during late July 2000. Based on this information, the difficulty in accessing this area, and the lack of any angler effort, the West Fork Gulkana River was excluded from the tagging portion of this study.

Fish implanted with transmitters must be large enough (tag must be < 2% weight of fish) to accommodate the radio transmitter (Winter 1983). Nearly all rainbow trout ≥ 420 mm FL were expected to be mature (Wuttig et al. 2004), and the behavior of rainbow trout of this size was expected to be representative of all mature-sized fish. The first healthy fish ≥ 420 mm FL caught from each location targeted was radiotagged, and each subsequent healthy fish was radiotagged until it was decided no more fish needed to be tagged from that exact location.

FISH CAPTURE AND TELEMETRY PROCEDURES

Rainbow trout were captured using hook-and-line gear and hoop traps baited with salmon roe. Hook-and-line terminal gear consisted of a pegged imitation egg bead with a piece of shrimp or salmon roe attached to a single hook, or a jig-head/grub-tail combination tipped with shrimp or salmon roe fished with a spinning rod. Baited hoop traps used were 1.2 m long and had 4 steel hoops. Each trap had two throats (positioned at the 2nd and 3rd hoop), which narrowed to a diameter of 7.5–10 cm. The hoop netting was constructed of 6 mm knotless nylon mesh, bound with #15 cotton twine, and treated with a water-based compound. Each trap was erected, or "stretched," using two approximately 1.8 m long pieces of 1.9 mm (¾ in) polyvinyl chloride (PVC) pipe with snap clips at each end of the pipe, which were clipped to the distal hoops of the trap. Salmon roe placed in a perforated plastic container was inserted into the cod end of the trap.

Table 1.–Planned and actual deployment of radio tags in the Gulkana River, 2010.

Section	Dates	Planned Deployment	Actual Deployment
Middle Fork	8/3/2010-8/4/2010	10	9
[a] Upper Mainstem	8/20/2010-8/24/2010	70	64
Lower Mainstem	8/21/2010-8/24/2010	20	18
West Fork Gulkana Confluence	9/29/2010	NA	9

[a] Includes the lower 1 rkm of the Middle Fork Gulkana River.

The upper mainstem was accessed using inflatable rafts. Sampling took place from 20–25 August 2010 (Table 1) by four crews of two people. A typical day consisted of all four rafts attempting to uniformly deploy ~14 tags per 16 rkm each day. A few more tags were allocated for the canyon area (rkm 108.5) because it was where the largest and highest density of mature-sized rainbow trout were found. Slightly fewer tags were allocated for a stretch above the canyon area because there were two long reaches of slow-moving water totaling ~10 rkm consisting mostly of unsuitable habitat for rainbow trout. Each night, the entire crew would camp together, and if it was deemed necessary, they would deploy hoop traps above and below camp in an attempt to capture mature-sized (≥420 mm FL) rainbow trout.

The lower mainstem was approximately 50.5 rkm in length and was sampled by two rafts with two people in each raft. Sampling took place during 21–25 August 2010 (Table 1). A lower-density tag deployment was scheduled in this stretch because it was known that rainbow trout densities were much lower compared to the upper mainstem segment. Also, more time per rkm was allocated here to ensure the criteria were achieved for minimum sample size. Working together downstream, the two crews alternately sampled likely habitats. Hoop traps were set above and below camp each evening attempting to catch fish suitable for tagging. A total of 20 tags were allocated for this reach, and it was anticipated that the pair of crews would be able to deploy four tags a day while covering 10 rkm per day. This schedule allowed the crew to complete the sampling in five working days.

The Middle Fork Gulkana River had a relatively short reach (i.e., ~4.5 rkm) of suitable summer rainbow trout habitat. This reach of river was accessed via 4- and 6-wheelers from the Swede Lake trail near mile 17 of the Denali Highway. Three days (2–4 August 2010) were allocated for a 3-person crew to sample the accessible areas of this habitat and attempt to radiotag 10 mature sized rainbow trout (Table 1).

Leftover tags were deployed at the confluence of the West Fork Gulkana River on 29 September 2010. This area was known to be a significant overwintering area, and it was presumed this area would be primarily inhabited by fish that summered throughout the drainage and provide a chance to document new habitat uses (e.g., summer use in the West Fork Gulkana River).

Radio tags were manufactured by Lotek Wireless Incorporated[1] (Model SR-M11-25). The tags measured 11x54 mm and weighed 9.5 g in air, and they were digitally encoded, equipped with a motion sensor, and programmed to operate daily for 12 hours between 0800 and 2000 h. Tag life was extended to 735 d using the programming schedule. The 100 unique tags emitted signals every 3.5 4.0 s and were divided evenly between two radio frequencies (149.700 and 149.800 MHz). The motion sensor emitted a unique code when a tagged fish was inactive. Inactivity was triggered after satisfying a preprogrammed time (24h) and sensitivity level (1) criterion. Inactive tags were interpreted as a dead fish.

Radio tags were surgically implanted following well-established procedures (Winter 1983; Summerfelt and Smith 1990). Fish selected for radiotagging were anesthetized using procedures outlined by Brown et al. (2002). Once a fish was anesthetized, fork length (FL) measurements were taken to the nearest mm before the surgery.

Anesthetized fish were placed ventral side up in a padded cradle and gills were irrigated with water/anesthesia solution throughout the surgical procedure. All surgical utensils were disinfected in a Nolvasan solution and rinsed with saline solution prior to surgery. Surgery began by cutting a 15 mm incision anterior to the pelvic girdle, along the left ventral side, about 5–10 mm from the midventral axis. A grooved director was placed into the coelomic cavity through the incision to direct a 16-gauge 25.4 cm hypodermic needle inserted from posterior of the pelvic girdle toward the incision (Brown et al. 2002). The tag antenna wire was routed from the incision past the pelvic girdle by threading the wire through the needle. Upon exit, the needle and grooved director were removed and the radio tag fully inserted into the coelomic cavity. The incision was sutured with 3 to 4 simple interrupted stitches of monofilament suture material (Wagner et al. 2000) and treated with a surgical adhesive (Vetbond). After surgery, fish were immediately placed into a large recovery tote filled with fresh river water to regain equilibrium prior to being released in a slow-flowing portion of the river.

Radiotagged rainbow trout were relocated using radio receivers manufactured by Lotek Wireless Incorporated (Model SRX 600) and aerial tracking techniques. A total of 17 tracking flights were performed with the first one being performed on 7 October 2010 and the last one on 27 June 2012 (Table 2). The frequency of surveys was highest during the spawning period (May and June) to better assess spring movements to probable spawning locations.

Aerial surveys were flown 100 to 300 m above ground elevation with a Piper Super Cub fixed-wing aircraft wired for telemetry. One radio receiver was used scanning each frequency for 5 s intervals. The receiver had an internal global positioning system (GPS) and an external magnetic antenna to automatically record the time and location of detected fish. Two H-antennas (148–152 MHz), one mounted on each wing, were connected to a splitter and controlled by a selecting switch.

A digitized map of the Gulkana River system was obtained from NHD (2011). Individual segments of the study area were extracted and then dissolved together to form a precise track of the Gulkana River drainage and imported into ArcGIS version 9.3.1. Distance markers were placed every 0.01 km along the centerline of the river, tributaries, and lakes using the "Convert Paths to Points" tool in Hawth's Analysis Tools (Beyer 2004).

[1] Product names are used for completeness but do not constitute endorsement.

Table 2.–Aerial tracking dates and the number of radiotagged rainbow trout by status category, Gulkana River, 2010–2012.

Survey Number	Survey Date	Number of Fish		
		Alive	Dead	Missing
1	10/7/2010	47	45	8
2	12/7/2010	42	47	11
3	3/30/2011	36	52	12
4	5/12/2011	32	55	13
[a]5	5/23/2011	24	44	32
6	5/30/2011	29	59	12
7	6/6/2011	27	61	12
8	6/13/2011	18	68	14
9	6/21/2011	17	66	17
10	6/28/2011	17	61	22
11	8/16/2011	9	71	20
12	10/20/2011	5	78	17
13	3/21/2012	4	66	30
14	5/15/2012	4	63	33
15	5/31/2012	4	61	35
[b]16	6/8/2012	4	29	67
[b]17	6/27/2012	4	40	56

[a] Only one antenna was working during survey 5.

[b] There were no live fish on one of the frequencies so that frequency was not scanned, leaving a higher number of "missing" fish.

Multiple locations, times, and signal strengths of detected fish were logged with the radio receivers during each survey. All data were downloaded from the aerial tracking receiver using Lotek Wireless Incorporated WinHost proprietary software and converted to a Microsoft Excel spreadsheet (Lotek 2005). Specific locations of tagged fish were determined for every survey by selecting the highest signal strength from a series of logged locations for each identified fish. For the data analyses, GPS locations for each fish were adjusted to the nearest distance marker using the "Point Global Snap" tool in ET Spatial Techniques (Tchoukanski 2010). To minimize overlapping fish locations for visual presentations, unsnapped locations of fish (i.e., where the airplane was when the highest signal strength was recorded) were used when making the figures for this report.

DATA ANALYSIS

After the location of each fish was plotted on a map, fish locations were labeled by survey, and individual fish were assigned a fate of active or alive (A), inactive or dead (I), or at-large or missing (AL). The fate of each fish was determined by examining the movement history and data provided by the motion sensors. Reviewing the movement history of each radiotagged fish was required because the motion sensor sometimes did not accurately reflect the fate of a tagged fish during a given survey. The history of sensor recordings for each fish was examined to decipher when and if the fish had died, and its fate was corrected for subsequent surveys. For example, a fish with an inactive signal for one or more surveys that later made significant movements and

emitted an active signal was considered alive for the inactive period. Conversely, when a fish emitted an active signal intermittently, all the while exhibiting no detectable movement throughout the tracking history, it was considered dead at the time when the first of consecutive inactive signals occurred. By the end, all fish were classified as alive, dead, or missing. All edited biological and telemetric data were entered and archived in an Excel spreadsheet (Appendix A).

At-large fish were excluded from the data analyses for that particular flight. These fish may have left the study area, experienced tag failure, or been overlooked during a particular survey. If the fish was relocated on subsequent surveys, its movement history was included in the final analysis.

Seasonal and Spawning Distribution

Single surveys were used to illustrate important seasonal distributions of radiotagged rainbow trout. Summer locations were displayed as locations of fish during early to mid-August, when rainbow trout are relatively stationary at their summertime feeding locations. Overwintering locations were defined as fish locations during March when fish are typically confined to select spots due to factors such as reduced water flow, thickening ice, and dissolved oxygen. These late winter locations probably represent the presence of critical overwintering habitat. Spawning locations were defined on a fish-by-fish basis by examining general movements (both distance and direction traveled) during the known spawning times (i.e., late May through early June). Time and duration fish spent at previously known spawning locations during this study were also used to help identify potential new spawning areas (i.e., if several fish migrated to a particular location during late May–early June and remained there throughout the known spawning duration, and then were tracked to different summering locations in August, spawning was assumed to have occurred there).

To confirm areas suspected to be spawning locations based on observed telemetry tracking, two attempts were made to ground-truth the tag information and document spawning in previously unconfirmed spawning areas. In both instances, a radio receiver was used to locate potential spawning fish and hook-and-line gear was used to assess, or attempt to assess, if fish were in spawning condition (e.g., if milt or eggs flowed freely). Additionally, visual confirmation of spawning (i.e., spawning fish, paired-up fish, or reds) was also attempted when the water clarity was conducive to see in. The first attempt was performed in 2011 when a crew of three people floated from the Middle Fork Gulkana River confluence to Sourdough Creek Campground from 30 May to 2 June. In 2012, a crew of three people flew to Minnesota Lake and hiked to an unnamed tributary of the West Fork Gulkana River on 4 June, where several radiotagged rainbow trout had migrated during the spawning season in 2011.

Movement

Movements of radiotagged fish were analyzed and summarized by plotting coordinates of all located fish deemed to be alive at the time of each survey onto a digitized map of the drainage using the program ArcGIS. The net movement (distance) between tracking events was determined by subtracting the river locations (i.e., 0.1 rkm assignments) of individual fish that were detected during consecutive surveys. These distances were summarized and reported as absolute values. Because the time between surveys varied throughout the study period, movements were summarized using descriptive statistics (i.e., mean, minimum, maximum, and SD). Fish that were not found alive during consecutive surveys were not used in the analysis.

Direction

As with movement, direction (upstream or downstream) was only calculated for fish found alive on consecutive surveys. When a fish either entered or left a tributary and traveled both upstream and downstream between surveys, the direction that the fish traveled the furthest was designated for that fish. For example, if a fish traveled down a tributary 3 rkm then up the mainstem 15 rkm, that fish was categorized as having traveled upstream for that time period.

Home Range

Home ranges were determined for fish that survived year one (tagging to 16 August 2011). To boost sample sizes for this analysis, fish that lived > 10 months were included in the home range analyses because most annual movements had occurred by the 10th survey on 28 June 2011 (e.g., the 10-month period encompassed summertime distribution, wintertime distribution and spawning distribution). Home range was determined as the distance measured between the upper- and lowermost extent of a radiotagged fish located within the drainage over the course of a year (or 10 months if the fish died or was not found during the 16 August 2011 survey). The home range of fish moving into or out of a tributary was the sum of the mainstem Gulkana River extent and the distance traveled in the tributary or tributaries.

Extent of spawning migrations were also calculated by tracking the distance fish swam from their overwintering locations to their presumed spawning locations. Specifically, this range analysis was done by measuring the distance between fish locations on 30 March 2011 (overwintering) and their presumed spawning area.

Summertime Fidelity

Fidelity to summertime tagging locations was examined by measuring the distances between August summer locations from one year to the next. This analysis was only performed for the first year of the study due to few fish surviving to the second year. Dates chosen were the time of tagging for the first summer location (August 2010) and the date of the survey (conducted on 16 August 2011). Nine fish radiotagged at the mouth of the West Fork Gulkana River were excluded from this analysis because they were probably not at their 2010 summering locations when tagged. Site fidelity was examined in August because this is a common time to conduct rainbow trout assessment surveys in Alaska and this information is important to future tagging or mark–recapture studies. Fidelity during other time periods could be examined in the future if warranted.

RESULTS

SUMMARY OF FISH CAPTURED

Four separate tagging trips took place to deploy all 100 radio tags in 2010 (Table 1). The first three tagging trips in August all had similar success with about 90% of the scheduled tags being deployed (9 out of 10 in the Middle Fork Gulkana River, 64 out of 70 in the upper mainstem, and 18 out of 20 in the lower mainstem). The remaining 9 tags were deployed in the mainstem at the confluence of the West Fork Gulkana in late September 2010 (Table 1). Radio tags were deployed across a range of 152 rkm (Figure 4). Lengths of the radiotagged fish ranged from 420 to 595 mm FL and averaged 453 mm FL (SD = 37.5; Table 3). More than 70% of all radiotagged rainbow trout were < 460 mm FL (Figure 5).

RADIOTRACKING

Overview

A total of 17 aerial surveys were conducted from 7 October 2010 to 27 June 2012 (Table 2). Aerial surveys were flown more frequently when rainbow trout were suspected to move the most for spawning (May and June). The survey on 12 May 2011 was hindered due to one antenna not working properly during the tracking flight. Information collected from this survey was used in all parts of the analyses. Rainbow trout were relocated over a cumulative range of 249 rkm throughout this study (Figure 6).

Reduced sample sizes associated with poor survival constrained the study results. The observed poor survival of radiotagged rainbow trout was not anticipated. The initial survey conducted on 7 October 2010 located 92 fish and only 47 were determined to be alive (Table 2). Mortality remained an issue throughout most of the study. Twenty-seven fish made it to the first spawning period (early June 2011 survey), but only 9 survived a full year to August 2011 (21 of the 30 that survived to spawning did not survive to August). Of the 9 fish that survived until August 2011, 4 survived to the second spawning period (June 2012). Individual fish information and date of final fates are provided in Appendix B.

Table 3.–Length statistics of radiotagged rainbow trout, Gulkana River, 2010.

	Radiotagged Fish ≥ 420 mm FL				
		Fork Length (mm)			
River Section	Number	Mean	SD	Min.	Max.
Middle Fork	9	443	26.1	420	505
Upper Mainstem	64	457	41.7	420	550
Lower Mainstem	18	450	34.0	420	595
West Fork Confluence	9	441	13.6	420	465
All Combined	100	453	37.5	420	595

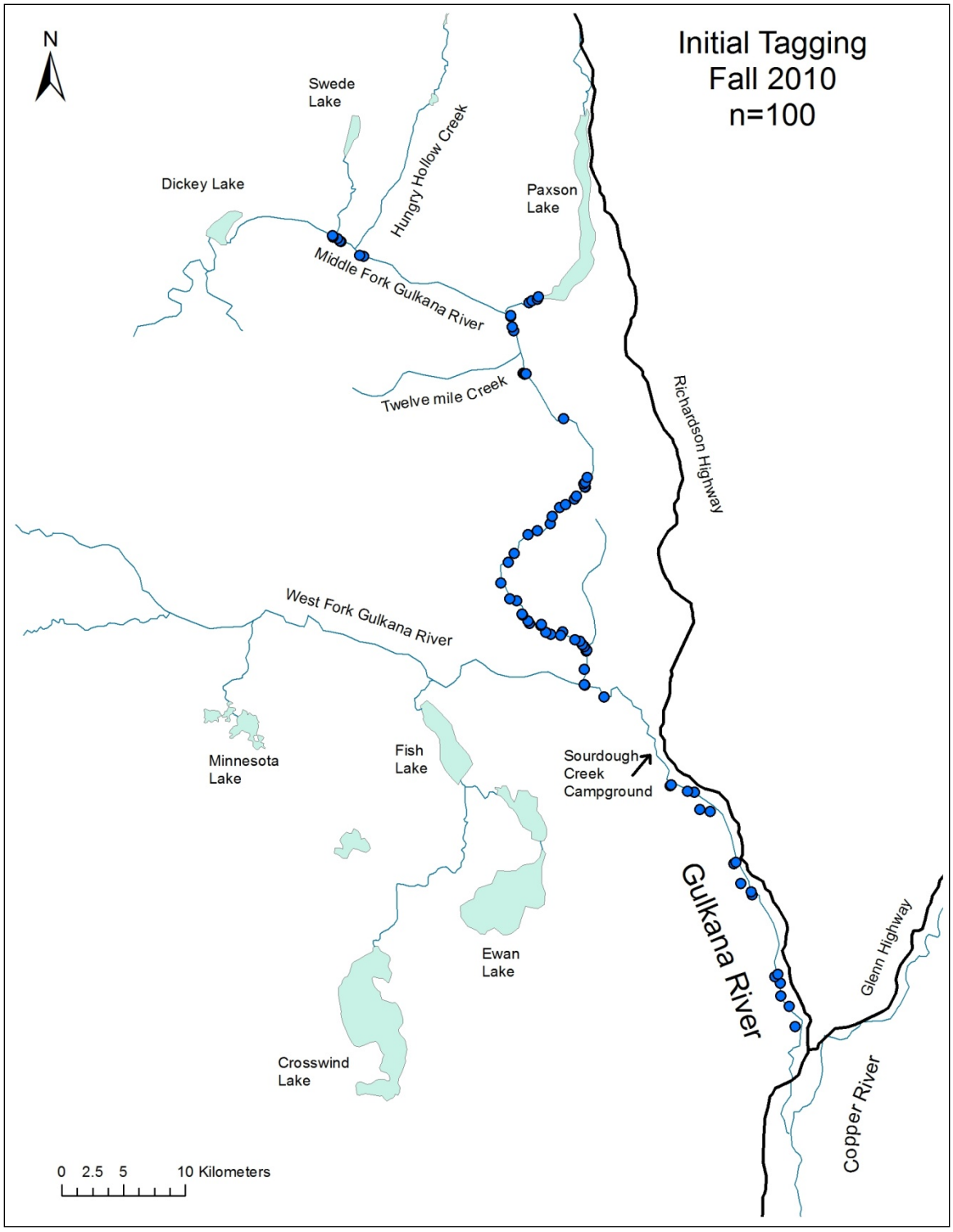

Figure 4.–Initial tagging locations of 100 rainbow trout during fall 2010. Each dot may represent more than one fish.

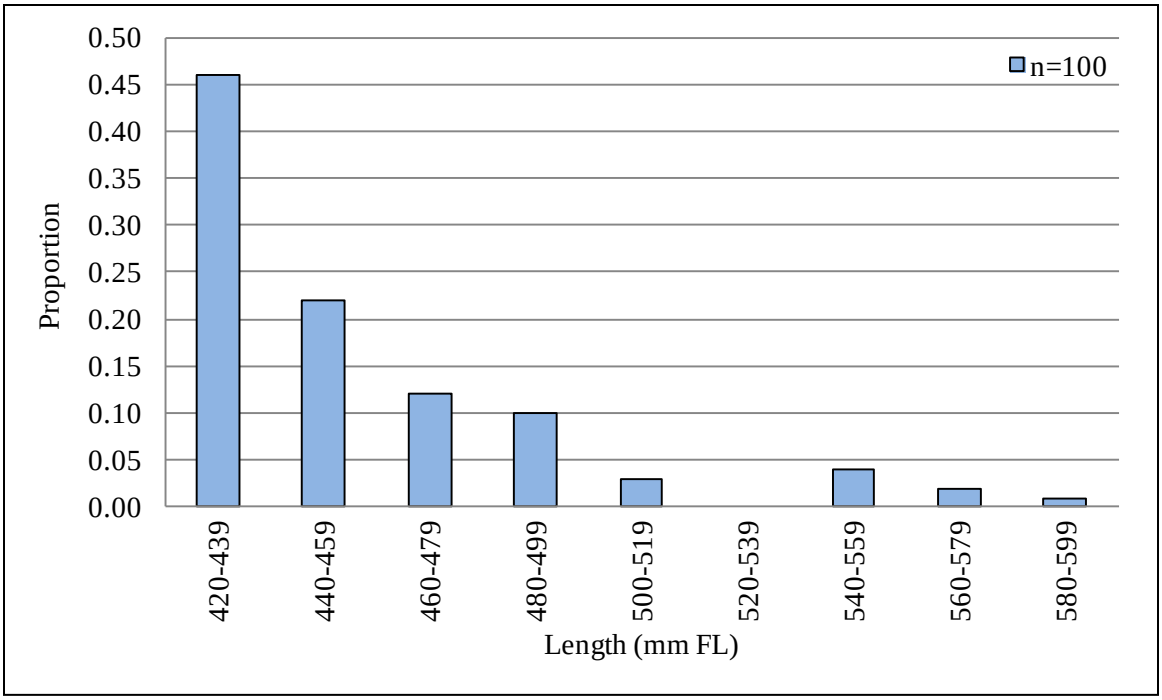

Figure 5.–Length histogram of rainbow trout caught and radiotagged in the Gulkana River, 2010.

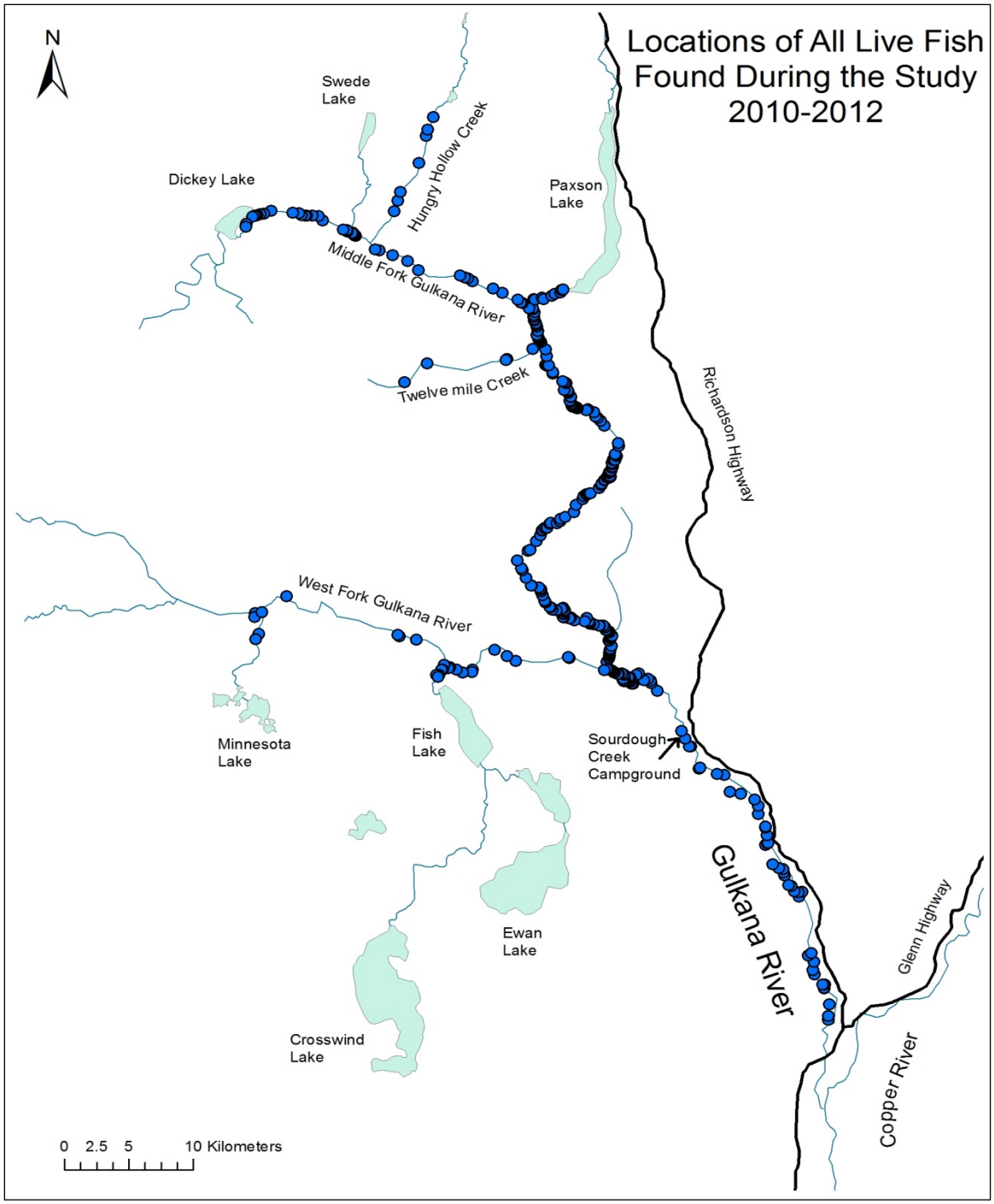

Figure 6.–All locations of live radiotagged fish found during all 17 aerial surveys.

Seasonal and Spawning Distribution

Overwintering locations were patchy during this study, especially in the upper mainstem Gulkana River (Figure 7). Thirty-six fish survived to the March survey in 2011, and only 4 survived to March 2012. It should be noted that 9 of these fish in 2011 and 2 in 2012 were tagged at the West Fork Gulkana River confluence on 29 September 2010, where they were

probably already at or near overwintering locations. Results of the telemetry work indicate that several areas appear important for overwintering. The four largest concentrations of fish (i.e., 3 or more) were found in the following locations: 1) a slow, deep reach extending 2 rkm above the Twelvemile Creek confluence (3 out of 36 possible fish here in 2011 and 0 out of 4 possible fish in 2012); 2) a slow, deep 3 rkm stretch of river about 5 rkm below Twelvemile Creek (7 out of 36 possible fish in 2011 and 2 out of 4 possible fish in 2012); 3) a 6 rkm stretch of river starting about 2.5 rkm above the West Fork Gulkana River and extending upstream (6 out of 36 possible fish in 2011 and 1 out of 4 fish in 2012); and 4) a reach from the West Fork Gulkana confluence extending downstream 2 rkm (11 out of 36 fish here in 2011, but 7 of these were tagged at the confluence on 29 September 2010).

All previously documented spawning areas had radiotagged fish travel to them during the spawning period, and two new areas were confirmed as spawning areas. Most of the rainbow trout were located at previously documented spawning areas: Dickey Lake outlet area (9 out of 30 tags in 2011 and 1 out of 4 tags in 2012), Hungry Hollow (4 out of 30 tags in 2011), and Twelvemile Creek (2 out of 30 tags in 2011; Figure 8). A major spawning area suspected by Fleming (2004) was confirmed on the eastern bend of the mainstem about 15 rkm below Twelvemile Creek (5 out of 30 tags in 2011 and 1 out of 4 tags in 2012). This 1.5 rkm area was ground-truthed during a float trip, and sampling with hook-and-line gear yielded a catch of 32 mature fish in spawning condition on 1 June 2011. Rainbow trout were visually observed spawning in this location also. The spawning area probably extended downstream because 2 radiotagged fish were located about 2 rkm below there during the 2011 spawning season, but this suspected area was not ground-truthed. A couple other spawning fish were captured while sampling in the mainstem above and below this concentration of fish, but these locations were not heavily used. It is very unlikely that any other significant spawning areas exist in the mainstem.

A new spawning area in an unnamed tributary of the West Fork Gulkana River that drains the Minnesota Lake complex was also documented by a combination of telemetry and the capture of actively spawning rainbow trout with hook-and-line gear (Figure 8). Four fish migrated to this new spawning area during known spawning time (3 in 2011 and 1 in 2012). A total of 15 mature rainbow trout in spawning condition were sampled in this tributary on 4 June 2012. Water temperature was recorded at 9.5° C that day (1:00 p.m.), and most spawning was considered complete because most fish were nearly spent and many vacant reds were observed. All spawning activity took place in the lower half of this tributary.

Results pertaining to summertime distribution were limited in this study. Survival was dismal over the course of the first year (9%), and because tags were deployed during late summer, consequent summer locations (i.e., 2011 and 2012) were probably more of a product of original tagging location. Interestingly, one of the nine fish that survived to the next summer was located at the outlet of Fish Lake in the West Fork Gulkana drainage (Figure 9). Other fish were detected in this location during other surveys, indicating it is an important area for rainbow trout, despite no fish originally being tagged from here. It is plausible that these fish might be feeding on outmigrating sockeye salmon *Oncorhychus nerka* smolt leaving Crosswind Lake.

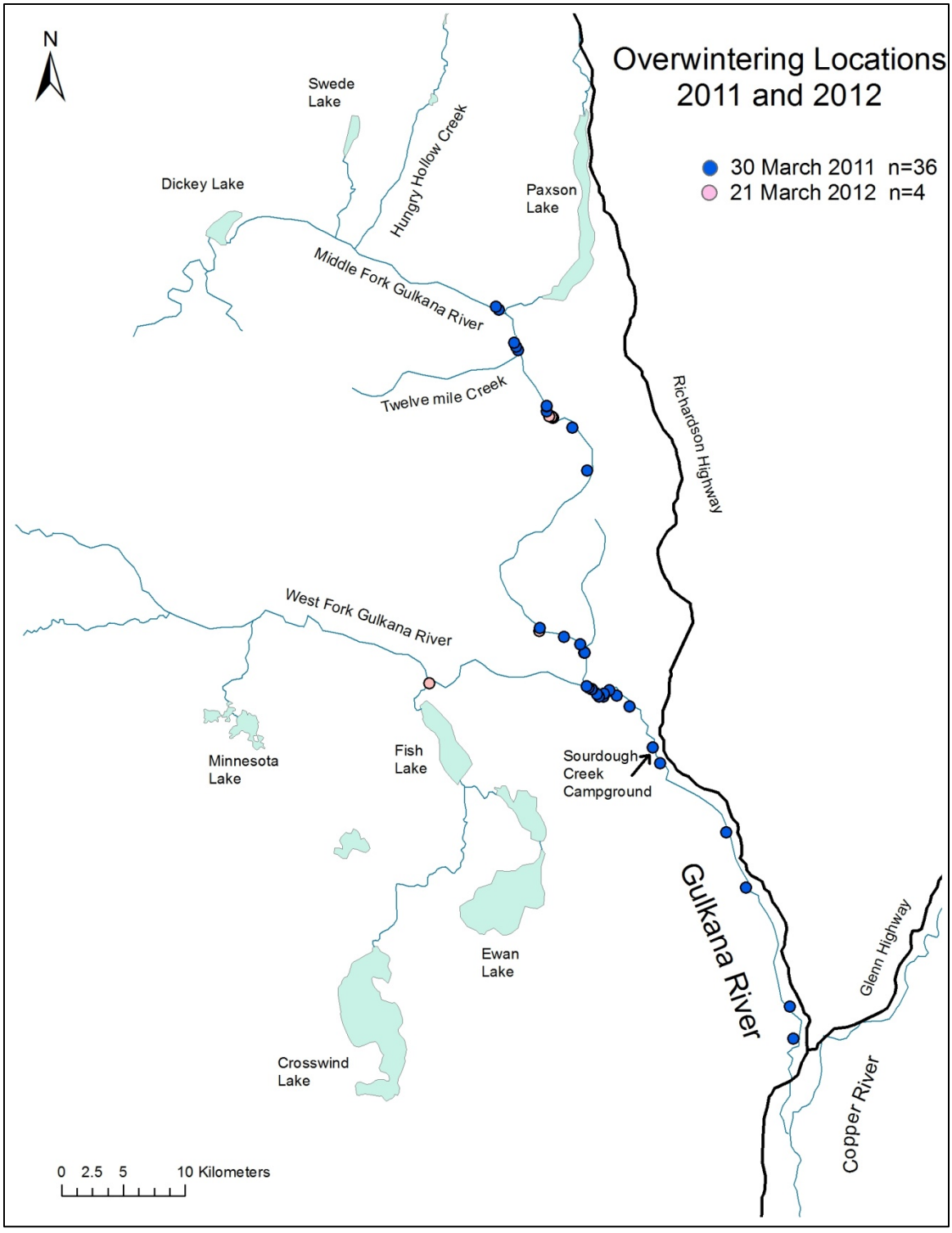

Figure 7.–Distribution of radiotagged rainbow trout during late winter, Gulkana River, 2011–2012.

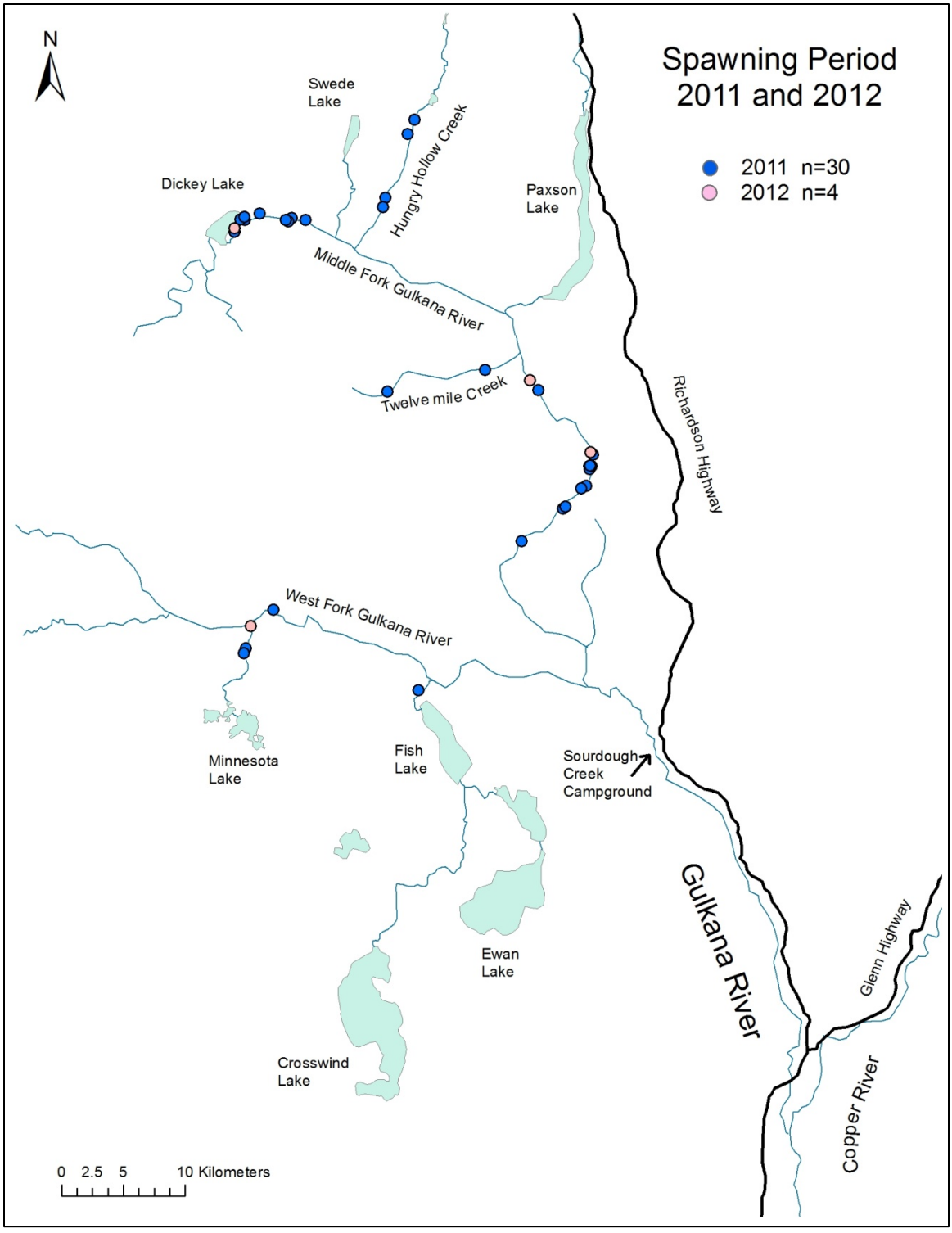

Figure 8.–Distribution of radiotagged rainbow trout during the spawning periods, Gulkana River, 2011–2012.

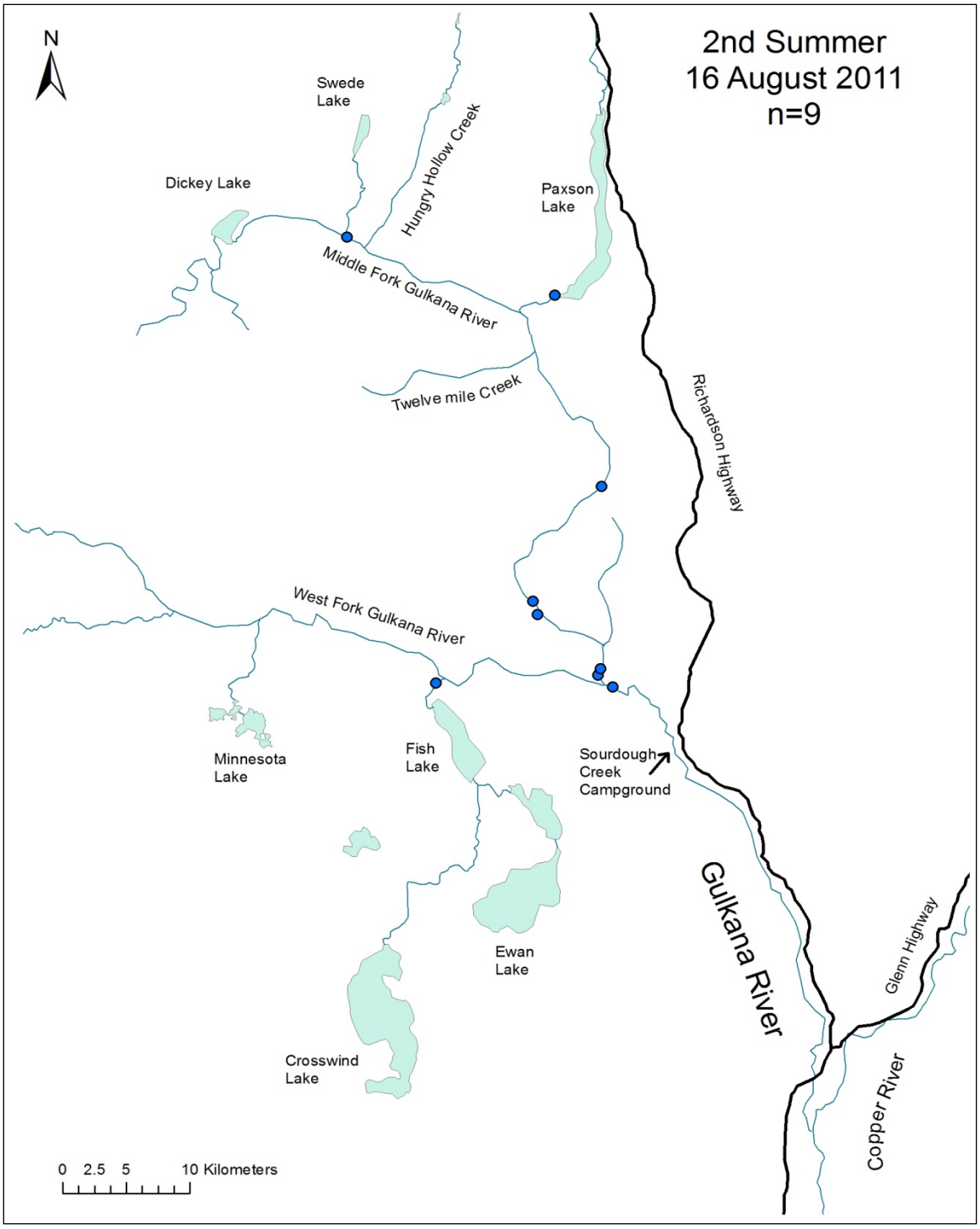

Figure 9.–Distribution of radiotagged rainbow trout during the summer season, Gulkana River, 2011.

Distance Traveled

Movement of fish between consecutive surveys revealed trends with regard to seasonal distribution and habitat preferences. Fish moved the greatest distances in the spring for spawning and moved very little during summer and again very little during winter (Table 4). During spring, aerial surveys were flown weekly from 12 May 2011 through 6 June 2011, a time period when rainbow trout were suspected to move the most for spawning. Movement during surveys peaked between 23 May and 30 May, when fish movement averaged 28.1 rkm with one fish traveling 95.2 rkm in just one week (Table 4). This movement suggests most fish were close to their spawning areas by the end of May. There was a decrease in mean movement between the 30 May 2011 and 6 June 2011 surveys, suggesting this is when peak spawning occurred. The next series of surveys showed a slight increase in movement suggesting post-spawning movements may have occurred. Movement became minimal in late June as mean annual movement was 4.4 rkm during the 1.5 month period between 28 June 2011 and 16 August 2011 (Table 4). Mean movement did increase to 15.7 rkm between 16 August 2011 and 20 October 2011 indicating that at some point during this duration, fish initiated movement to overwintering areas. Mean movement between 20 October 2011 and the next survey on 3 March 2012 (3.7 rkm) indicated that migrations to overwintering areas were probably complete by the 20 October 2011 survey. Reduced sample sizes compromised the results past these dates, but pre-spawning movement was visible starting in mid-May 2012.

Direction Traveled

Direction moved between consecutive surveys revealed interesting behavior. Movements to spawning areas were almost all upstream. During the two surveys in mid- to late May 2011, 95% of the fish moved upstream during both surveys (Table 5). This time period is also when the greatest distances were covered (Tables 4 and 5). Information from the subsequent survey also supports the idea that peak spawning occurred between 30 May 2011 and 6 June 2011 when the proportion of fish traveling upstream dropped to half. Post-spawning movements were shown when 76% of the fish moved back downstream between the 6 June 2011 and 13 June 2011 surveys. During all other time periods not associated with pre-spawning movements, movements were generally downstream. Between 61% and 70% of radiotagged fish moved downstream between the three sets of surveys from the time of tagging to 3 March 2011 (Table 5). Sample sizes were limited during the second year of the study, but results yielded similar trends.

Home Range

Gulkana River rainbow trout exhibited some relatively large ranges during this study. A total of 9 fish survived a full year during this study, and their mean home range was 50.9 rkm (SD = 21.1; Table 6). The largest home range of these fish was 90.9 rkm and the smallest was 31.1 rkm. Movement data suggest that very little movement occurred in July and August (Table 4); therefore, to boost sample sizes of this analysis, the mean home range of 17 fish that lived from the time of tagging to the end of June 2011 was also examined (Table 6). These fish had a mean home range of 58.8 rkm (SD = 29.2), and two fish had ranges greater than 100 rkm (102.5 and 128.5 rkm).

Table 4.–Summary of movement information for radiotagged rainbow trout detected during consecutive surveys in the Gulkana River, 2010–2012.

Dates of Surveys	Days Between Surveys	Sample Size	Absolute Movement (rkm)		Upstream Movement (rkm)		Downstream Movement (rkm)	
			Mean	SD	Max.	Min.	Max.	Min.
Tagging 10/7/10	8-65	47	6.4	9.4	16.3	< 0.1	38.9	< 0.1
10/7/10 12/7/10	61	41	5.0	8.0	27.7	< 0.1	29.0	0.1
12/7/10 3/30/11	113	36	1.5	2.6	3.7	< 0.1	14.3	< 0.1
3/30/11 5/12/11	43	31	4.5	5.7	22.5	< 0.1	14.5	< 0.1
5/12/11 5/23/11	11	22	18.6	17.8	68.2	0.2	7.8	7.8
5/23/11 5/30/11	7	21	28.1	24.3	95.2	3.1	0.2	0.2
5/30/11 6/6/11	7	27	10.9	15.7	55.4	< 0.1	44.0	0.1
6/6/11 6/13/11	7	18	14.8	19.4	0.7	0.1	64.8	0.3
6/13/11 6/21/11	8	16	9.0	12.3	3.3	< 0.1	40.4	0.1
6/21/11 6/28/11	7	17	10.5	19.8	16.6	< 0.1	81.0	< 0.1
6/28/11 8/16/11	49	9	4.4	6.8	2.3	0.3	20.4	< 0.1
8/16/11 10/20/11	65	5	15.7	14.6	NA	NA	35.5	< 0.1
10/20/11 3/3/12	135	4	3.7	4.8	3.9	0.2	10.4	0.1
3/3/12 5/15/12	73	4	8.3	5.5	14.6	1.7	NA	NA
5/15/12 5/31/12	16	4	21.8	15.8	40.0	4.7	NA	NA
5/31/12 6/8/12	8	4	14.7	15.6	8.0	7.9	38.0	5.0
6/8/12 6/27/12	19	4	2.3	3.0	2.0	0.3	6.6	< 0.1

Table 5.–Movement direction summary of radiotagged rainbow trout in the Gulkana River, 2010–2012.

Dates of Surveys	Days Between Surveys	Number Upstream	Proportion Upstream	Number Downstream	Proportion Downstream
Tagging 10/7/10	8-65	14	0.30	33	0.70
10/7/10 12/7/10	61	13	0.32	28	0.68
12/7/10 3/30/11	113	14	0.39	22	0.61
3/30/11 5/12/11	43	21	0.68	10	0.32
5/12/11 5/23/11	11	21	0.95	1	0.05
5/23/11 5/30/11	7	20	0.95	1	0.05
5/30/11 6/6/11	7	13	0.48	14	0.52
6/6/11 6/13/11	7	4	0.24	13	0.76
6/13/11 6/21/11	8	5	0.31	11	0.69
6/21/11 6/28/11	7	5	0.29	12	0.71
6/28/11 8/16/11	49	3	0.33	6	0.67
8/16/11 10/20/11	65	0	0.00	5	1.00
10/20/11 3/3/12	135	2	0.50	2	0.50
3/3/12 5/15/12	73	4	1.00	0	0.00
5/15/12 5/31/12	16	4	1.00	0	0.00
5/31/12 6/8/12	8	2	0.50	2	0.50
6/8/12 6/27/12	19	2	0.50	2	0.50

Table 6.–Minimum, maximum, and mean home range of radiotagged rainbow trout in the Gulkana River from 2010 to 2011. Home range was calculated using the distance traveled from the uppermost extent to the lowermost extent for individual rainbow trout over the course of a designated time period.

Time Period	Active Fish (*n*)	Home Range (rkm) Mean	SD	Max.	Min.
Tagging (8/3-9/29/2010) to next summer (8/16/2011)	9	50.9	21.1	90.9	31.1
Tagging[a] (8/3-9/29/2010) to next summer (6/28/2011)	17	58.8	29.2	128.5	29.4
Overwintering[b] (3/30/2011) to next spawning period	30	60.1	34.2	134.5	9.2

[a] To bolster sample sizes, home range was also examined from the time of tagging to the 6/28/2011 survey. This time period (10 to 11 months) captures almost all of the seasonal migrations over the course of a year.

[b] The spawning period is defined as either the 5/30/2011 survey or the 6/6/2011 survey, whichever best represented that fish's spawning location.

Lastly, because fish movement was greatest for the spawning period, we examined home ranges (in this case, almost entirely spawning migrations) defined as the distance traveled between overwintering (30 March 2011) and the spawning period. We had 30 fish survive this time period, and their mean spawning migration distance was 60.1 rkm (SD = 34.2; Table 6). Interestingly, 6 of these fish traveled > 100 rkm (100.9, 102.3, 111.6, 121.2, 128.5, and 134.5 rkm) to their spawning areas. None of these 6 fish survived longer than two months after spawning (the survey on 6 August 2011).

Summertime Fidelity

Mean summertime fidelity was calculated for fish that survived from the time of tagging to the summer of 2011. A total of 9 fish survived to the 16 August 2011 survey. Of these, 2 were not included in the analyses because they were tagged in late September 2010 (i.e., they were probably not at their summering locations when tagged). The 7 fish tagged in August 2010 that survived until 16 August 2011 had a mean summertime fidelity of 6.6 rkm (Table 7). Of these 7 fish, 4 of them were located < 1 rkm from their previous year's summertime location.

As with home range analysis, locations of fish during the late June survey were also examined to boost sample sizes. A total of 11 (4 more were added) of the fish tagged in August 2010 survived to the 28 June 2010 survey, and they had a summertime fidelity of 5.6 rkm (7 fish were found < 1.0 rkm from their 2010 tagging location; Table 7).

DISCUSSION

Poor initial survival of radiotagged rainbow trout compromised the results of this study. Over half the fish did not survive to the first aerial survey, and mortality remained an issue throughout the study. It is believed that water temperature during the tagging period (August 2010) was the major factor in poor initial survival. Our goal was to radiotag rainbow trout during their summertime distribution. It was believed that waiting until August would promote initial survival because water temperatures were assumed to begin decreasing with approaching fall weather patterns. Unfortunately, August was unusually warm and the water temperatures were not as low as expected, ranging from 12° to 17° C. Of the 91 fish tagged in August, 42% of them survived to the first survey on 7 October 2010. In stark contrast, 9 fish tagged at the West Fork Gulkana River on 29 September (the water was approaching freezing) had 100% initial survival (the first fish did not die until 8 months later). In the future, it is recommended to tag fish when the water temperatures are likely to be cooler. Also, the 9 rainbow trout radiotagged at the

confluence of the West Fork Gulkana River on 29 September 2010 not only had great survival but also ended up migrating to all of the major spawning areas (Figure 10). It also appears that some of the fish that overwinter near the West Fork confluence spend their summers in the West Fork Gulkana River, increasing the odds of finding new seasonal distributions within the drainage. If another telemetry study is conducted in the future, strong consideration should be given to tagging fish in the fall, with a substantial proportion of tags being placed at the West Fork Gulkana confluence.

Table 7.–Fidelity of radiotagged rainbow trout to summertime tagging locations measured in river kilometers (rkm) and reported as mean, maximum, and minimum distances. Summer surveys were used to describe summertime fidelity, Gulkana River, 2010–2011.

	Active	Measured Distance (rkm)		
Time Period	Fish (*n*)	Mean	Max.	Min.
Tagging (8/3-8/24/2010) to 2nd summer (8/18/2011)	7	6.6	22.7	0.1
Tagging (8/3-8/24/2010) to 2nd summer (6/28/2011)	11	5.6	22.7	0.1

[a] To bolster sample sizes, summertime fidelity was also examined from the time of tagging to the 6/28/2011 survey. By 6/28/2011, movement to summering areas was nearly complete.

This study documented a highly migratory population of rainbow trout in Alaska. Mean annual riverine home ranges of 50–60 rkm is substantial for this species. Twenty percent of the fish in this study that survived from 30 March 2011 to the spawning period traveled more than 100 rkm to spawn. The spawning migration window is relatively short (2–3 weeks) and coincides with high water flows due to spring runoff. Despite high flows, tagged fish often swam upstream at a rate of 50 rkm in 7 days, with one fish in particular traveling 95 rkm in a 7-day period.

Other extensive migrations of rainbow trout have been reported in Alaska rivers, but it appears the rainbow trout of the Gulkana River may be the most migratory ever documented in Alaska. Schwanke et al. (2014) reported mean annual home ranges of 21 and 19 rkm in the Kanektok River, with four unique fish having annual home ranges > 70 rkm. One of these fish had an estimated home range of 108.7 rkm the first year of the study and 112.1 rkm the second year. Meka et al. (2003) documented a fish with a home range of ~102 rkm over the course of a year in the Alagnak River drainage, and Nelle (2002) observed several fish with a home range > 50 rkm (max of 68 rkm) over a one-year period in the Togiak River.

The Gulkana River rainbow trout population is a true fringe population, living at the northernmost extent of any wild rainbow trout population in North America. It is possible that this population may experience high natural mortality due to this relatively extreme environment and migratory requirements. Of the 6 fish that traveled > 100 rkm (100.9, 102.3, 111.6, 121.2, 128.5, and 134.5 rkm) to their spawning areas, none survived the summer. Additionally, of the 30 fish that presumably lived to the spawning period in 2011, only 9 were still alive during the August 2011 survey. Sample sizes are too small to link spawning migration length or physical hardships (also hard to classify) to survival, but it is nonetheless very plausible that a relationship exists.

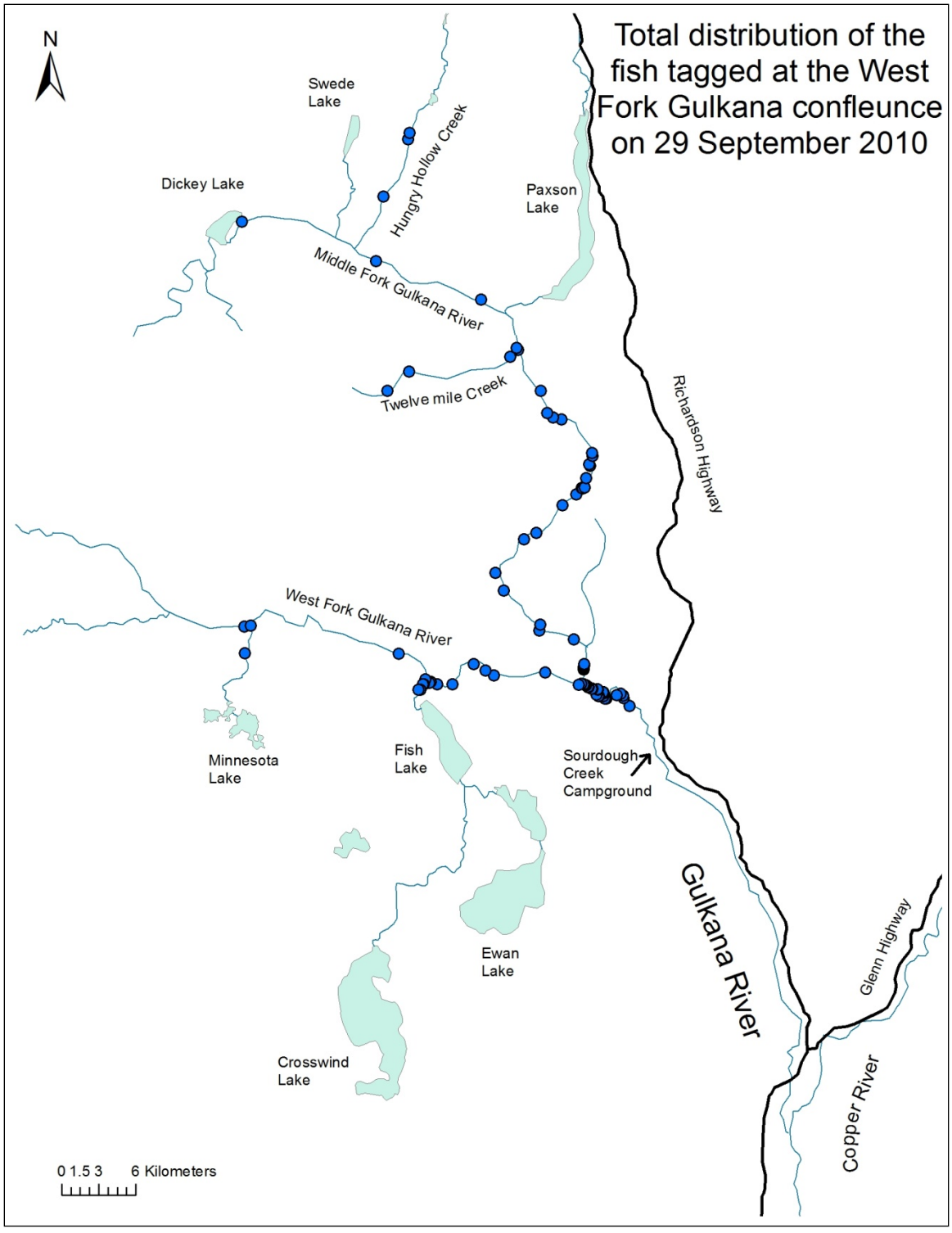

Figure 10.–All locations of radiotagged rainbow trout that were originally tagged at the West Fork Gulkana confluence on 29 September 2010.

Insight into spawning behavior can be more easily assessed when studies span consecutive spawning seasons. Skip spawning is difficult to assess, but it has been documented in the Naknek River (Schwanke 2009), and speculated in the Kanektok River (Schwanke et al. 2014) when a few radiotagged fish (< 5) exhibited substantial migrations to putative spawning areas during the first year, but not the second year of a two-year study. It should be noted that during both of these studies, the majority of fish provided only partial evidence of skip spawning, and that the trait may have only been displayed in a small proportion of the fish. The ability to assess skip spawning during this study was severely limited due to poor survival. Only 4 fish survived to the second spawning study; of these, two made migrations to documented spawning areas during one spawning period but not the other. One fish made a spawning migration to a known spawning area in 2011 but not in 2012. The other did not make a spawning migration in 2011 but did in 2012 (this fish may not have been mature the first spring). In both cases, the year they did not make a spawning migration, they went straight from overwintering areas to observed summering areas, where they remained. Larger sample sizes would be needed to make more definitive conclusions about the possibility or prevalence of skip spawning. Skip spawning is a trait that is typically more prevalent in northern populations, particularly those on the fringes of their distribution.

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APPENDICES

Appendix A1.–Summary of data archives for the Gulkana River rainbow trout telemetry study, 2010–2012.

Year	Data File[a]	Software
2012	Gulkana River_rainbowtrout_telemtrydata.xls	Microsoft Excel

[a] Data files are archived and available from the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

Appendix B1.–Date of capture, length, tag information, release location, final fate, date last found alive, days alive, and range of each radiotagged rainbow trout, Gulkana River, 2010–2012.

Date	FL (mm)	Radio Tag Frequency 162.xxx MHz	Radio Tag Code	River Segment	Latitude Decimal Degrees	Longitude Decimal Degrees	Final Fate	Last Date Found Alive	Days Alive	Maximum Range (km)
8/21/2010	475	700	3	LM	62.4864	-145.474	Mortality	8/21/2010	0	0.0
8/24/2010	435	700	4	LM	62.3237	-145.371	Mortality	6/28/2011	308	128.5
8/23/2010	420	700	5	UM	62.6552	-145.734	Mortality	8/23/2010	0	0.0
8/23/2010	420	700	6	UM	62.6861	-145.683	Mortality	8/23/2010	0	0.0
8/3/2010	425	700	7	MF	62.9191	-145.934	Mortality	8/3/2010	0	0.0
8/22/2010	465	700	8	UM	62.7028	-145.627	Mortality	5/23/2011	274	38.5
8/23/2010	430	700	9	UM	62.6248	-145.698	Mortality	8/23/2010	0	0.0
8/21/2010	440	700	10	UM	62.8447	-145.665	Mortality	10/7/2010	47	0.4
8/21/2010	435	700	11	UM	62.8343	-145.663	Mortality	6/6/2011	289	42.6
8/21/2010	425	700	12	UM	62.8024	-145.655	Mortality	3/30/2011	221	7.3
9/29/2010	430	700	13	UM	62.5746	-145.624	Mortality	6/6/2011	250	101.4
8/21/2010	465	700	14	UM	62.8019	-145.658	Mortality	8/21/2010	0	0.0
8/22/2010	465	700	15	UM	62.6976	-145.642	Mortality	8/22/2010	0	0.0
8/22/2010	480	700	16	UM	62.6923	-145.646	Mortality	8/22/2010	0	0.0
8/22/2010	565	700	17	UM	62.7080	-145.604	Mortality	8/22/2010	0	0.0
8/22/2010	445	700	18	UM	62.7187	-145.583	Mortality	8/22/2010	0	0.0
9/29/2010	435	700	19	UM	62.5746	-145.624	Mortality	6/28/2011	272	58.6
8/24/2010	440	700	20	UM	62.6198	-145.679	Mortality	8/24/2010	0	0.0
8/23/2010	435	700	21	UM	62.6428	-145.724	Mortality	6/28/2011	309	74.5
8/21/2010	460	700	22	UM	62.8371	-145.665	Mortality	6/6/2011	289	51.4
8/24/2010	420	700	23	UM	62.6153	-145.676	Mortality	8/16/2011	357	35.3
8/24/2010	440	700	24	UM	62.5847	-145.62	Mortality	10/20/2011	422	46.8
8/22/2010	445	700	25	LM	62.4163	-145.421	Mortality	5/23/2011	274	7.6
8/22/2010	430	700	26	LM	62.4706	-145.454	Mortality	8/22/2010	0	0.0
9/29/2010	445	700	27	UM	62.5746	-145.624	Mortality	5/30/2011	243	115.2

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Date	FL (mm)	Radio Tag Frequency 162.xxx MHz	Radio Tag Code	River Segment	Latitude Decimal Degrees	Longitude Decimal Degrees	Final Fate	Survey Date of Final Fate Assignment	Days Alive	Maximum Range (km)
8/23/2010	425	700	28	UM	62.6309	-145.706	Mortality	6/6/2011	287	88.2
8/22/2010	555	700	29	UM	62.7187	-145.583	Mortality	6/6/2011	288	63.0
8/4/2010	455	700	30	MF	62.9026	-145.894	Mortality	5/12/2011	281	25.4
8/21/2010	440	700	31	LM	62.4939	-145.510	Mortality	8/21/2010	0	0.0
9/29/2010	440	700	32	UM	62.5746	-145.624	Mortality	6/28/2011	272	102.3
8/24/2010	435	700	33	UM	62.5978	-145.614	Mortality	8/24/2010	0	0.0
8/4/2010	455	700	34	MF	62.9162	-145.926	Mortality	8/4/2010	0	0.0
8/24/2010	435	700	35	LM	62.3321	-145.381	Mortality	8/24/2010	0	0.0
8/22/2010	425	700	36	UM	62.7187	-145.583	Mortality	8/22/2010	0	0.0
8/23/2010	490	700	37	UM	62.6685	-145.721	Mortality	10/7/2010	45	0.2
8/22/2010	420	700	38	LM	62.4736	-145.470	Mortality	6/6/2011	288	121.3
8/5/2010	420	700	39	MF	62.9141	-145.923	Mortality	8/5/2010	0	0.0
8/22/2010	595	700	40	UM	62.7187	-145.583	Mortality	8/22/2010	0	0.0
9/29/2010	440	700	41	UM	62.5746	-145.624	Mortality	6/6/2011	250	69.0
8/23/2010	445	700	42	LM	62.4093	-145.406	Missing	8/23/2010	0	0.0
8/24/2010	425	700	43	LM	62.3085	-145.365	Missing	8/24/2010	0	0.0
8/21/2010	485	700	44	UM	62.8371	-145.665	Mortality	10/7/2010	47	9.5
8/25/2010	420	700	45	UM	62.5627	-145.594	Mortality	12/7/2010	104	1.1
8/24/2010	420	700	46	UM	62.6018	-145.615	Mortality	8/24/2010	0	0.0
8/24/2010	425	700	47	UM	62.6034	-145.619	Mortality	12/7/2010	105	5.5
8/23/2010	440	700	48	UM	62.6237	-145.699	Mortality	12/7/2010	106	0.2
8/22/2010	470	700	49	UM	62.7178	-145.586	Mortality	8/22/2010	0	0.0
8/24/2010	465	700	50	UM	62.5746	-145.624	Mortality	6/13/2011	293	35.3
8/22/2010	430	700	51	UM	62.7097	-145.600	Mortality	8/22/2010	0	0.0
8/24/2010	445	700	52	UM	62.5744	-145.624	Mortality	8/24/2010	0	0.0
8/3/2010	505	700	53	MF	62.9174	-145.933	Mortality	8/3/2010	0	0.0

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Appendix B1.–Page 3 of 4.

Date	FL (mm)	Radio Tag Frequency 162.xxx MHz	Radio Tag Code	River Segment	Latitude Decimal Degrees	Longitude Decimal Degrees	Final Fate	Survey Date of Final Fate Assignment	Days Alive	Maximum Range (km)
8/3/2010	435	800	3	MF	62.9174	-145.933	Alive	6/27/2012	694	43.8
8/22/2010	465	800	4	UM	62.7050	-145.618	Mortality	6/28/2011	310	29.4
8/20/2010	458	800	5	UM	62.8541	-145.631	Mortality	8/20/2010	0	0.0
8/24/2010	455	800	6	UM	62.5744	-145.624	Mortality	8/24/2010	0	0.0
8/20/2010	420	800	7	UM	62.8549	-145.621	Mortality	8/20/2010	0	0.0
8/22/2010	550	800	8	UM	62.7187	-145.583	Mortality	8/22/2010	0	0.0
8/21/2010	445	800	9	UM	62.7664	-145.605	Mortality	8/21/2010	0	0.0
8/23/2010	490	800	10	UM	62.6401	-145.714	Mortality	8/16/2011	358	87.2
9/29/2010	425	800	11	UM	62.5746	-145.624	Alive	6/27/2012	637	31.5
8/24/2010	420	800	12	UM	62.6051	-145.621	Mortality	8/24/2010	0	0.0
8/24/2010	420	800	13	UM	62.6071	-145.630	Mortality	8/24/2010	0	0.0
8/23/2010	460	800	14	LM	62.4071	-145.406	Mortality	5/30/2011	280	134.9
8/24/2010	420	800	15	UM	62.6114	-145.653	Mortality	8/24/2010	0	0.0
8/5/2010	435	800	16	MF	62.9143	-145.922	Mortality	10/7/2010	63	38.9
8/22/2010	430	800	17	LM	62.4325	-145.425	Missing	8/22/2010	0	0.0
8/24/2010	490	800	18	UM	62.5970	-145.615	Mortality	8/24/2010	0	0.0
8/22/2010	435	800	19	LM	62.4093	-145.406	Mortality	8/22/2010	0	0.0
8/24/2010	425	800	20	UM	62.6203	-145.678	Mortality	8/24/2010	0	0.0
8/22/2010	450	800	21	UM	62.7050	-145.618	Mortality	8/22/2010	0	0.0
8/24/2010	440	800	22	UM	62.6136	-145.666	Mortality	8/24/2010	0	0.0
8/22/2010	425	800	23	UM	62.7164	-145.582	Mortality	6/6/2011	288	9.8
8/24/2010	435	800	24	UM	62.5746	-145.624	Mortality	10/7/2010	44	8.6
8/21/2010	450	800	25	LM	62.4934	-145.511	Mortality	6/28/2011	311	42.8
8/21/2010	490	800	26	UM	62.8371	-145.665	Mortality	5/12/2011	264	12.5
8/24/2010	420	800	27	UM	62.6135	-145.648	Mortality	6/13/2011	293	27.7
8/22/2010	480	800	28	UM	62.7178	-145.586	Mortality	8/22/2010	0	0.0

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Appendix B1.–Page 4 of 4.

Date	FL (mm)	Radio Tag Frequency 162.xxx MHz	Radio Tag Code	River Segment	Latitude Decimal Degrees	Longitude Decimal Degrees	Final Fate	Survey Date of Final Fate Assignment	Days Alive	Maximum Range (km)
8/22/2010	460	800	29	UM	62.6885	-145.668	Mortality	8/16/2011	359	31.1
9/29/2010	460	800	30	UM	62.5746	-145.624	Mortality	6/28/2011	272	70.7
8/22/2010	485	800	31	UM	62.7187	-145.583	Mortality	12/7/2010	107	34.7
8/22/2010	435	800	32	LM	62.4315	-145.427	Mortality	8/22/2010	0	0.0
8/24/2010	455	800	33	LM	62.3479	-145.382	Mortality	8/24/2010	0	0.0
8/23/2010	435	800	34	UM	62.6299	-145.705	Mortality	8/23/2010	0	0.0
8/22/2010	550	800	35	UM	62.7154	-145.582	Mortality	5/30/2011	281	61.3
8/24/2010	420	800	36	LM	62.3410	-145.379	Mortality	5/12/2011	261	8.3
8/21/2010	500	800	37	LM	62.4874	-145.485	Mortality	8/21/2010	0	0.0
8/23/2010	560	800	38	LM	62.3462	-145.387	Missing	8/23/2010	0	0.0
8/22/2010	420	800	39	UM	62.7217	-145.578	Mortality	8/22/2010	0	0.0
8/21/2010	500	800	40	UM	62.8462	-145.666	Mortality	8/21/2010	0	0.0
8/20/2010	495	800	41	UM	62.8525	-145.635	Mortality	5/12/2011	265	9.8
8/21/2010	420	800	42	UM	62.8034	-145.659	Mortality	10/7/2010	47	25.0
8/3/2010	430	800	43	MF	62.9182	-145.933	Mortality	8/3/2010	0	0.0
8/20/2010	425	800	44	UM	62.8557	-145.620	Alive	6/27/2012	677	55.9
8/23/2010	550	800	45	UM	62.6745	-145.710	Mortality	12/7/2010	106	15.5
8/22/2010	420	800	46	UM	62.7187	-145.583	Mortality	8/22/2010	0	0.0
9/29/2010	430	800	47	UM	62.5746	-145.624	Mortality	6/28/2011	272	34.9
8/23/2010	495	800	48	UM	62.6861	-145.683	Mortality	8/16/2011	358	90.9
9/29/2010	465	800	49	UM	62.5746	-145.624	Alive	6/27/2012	637	35.9
8/21/2010	450	800	50	UM	62.8343	-145.663	Missing	8/21/2010	0	0.0
8/4/2010	430	800	52	MF	62.9010	-145.888	Mortality	8/4/2010	0	0.0