Fishery Data Series No. 04-18

Stock Status and Population Biology of the Copper River Steelhead

Final Report for Studies 01-148 and 03-001
USFWS Office of Subsistence Management
Fishery Information Service Division

by

Klaus Wuttig,

Jeff Olsen

and

Douglas Fleming

September 2004

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

Symbols and Abbreviations

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

Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

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

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

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

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

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, 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	$\geq$
harvest per unit effort	HPUE
less than	$<$
less than or equal to	$\leq$
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 REPORT NO. 04-18

STOCK STATUS AND POPULATION BIOLOGY OF THE COPPER RIVER STEELHEAD

By
by
Klaus Wuttig, Douglas Fleming
Division of Sport Fish, Fairbanks
and
Jeff Olsen
U.S. Fish and Wildlife Service

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

September 2004

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

Klaus Wuttig, Douglas Fleming
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599, USA
and
Jeff Olsen
U.S. Fish and Wildlife Service, Anchorage
3601 C. Street, Anchorage, AK 99503 USA

This document should be cited as:
Wuttig, K., D. Fleming, and Jeff Olsen. 2004. Stock status and population biology of the Copper River steelhead, Fishery Data Series No. 04-18, Anchorage.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

Appendix **Page**

ABSTRACT

From 2001 to 2002, abundance and genetic information was collected on two of what is currently believed to be the two most significant steelhead *Oncorhynchus mykiss* stocks in the Copper River drainage, near Dickey Lake (Gulkana River drainage) and Hanagita Lakes (Chitina River drainage). Because both non-anadromous rainbow trout and anadromous steelhead occur sympatrically at the Dickey Lake spawning area, the study's scope was widened to include estimation of abundance and genetic sampling of non-anadromous rainbow trout. To facilitate within-drainage genetic relatedness, genetic samples were also collected in 2003 from a sympatric population of rainbow trout and steelhead at another spawning tributary within the Gulkana River, Hungry Hollow Creek. At all locations genetic samples were collected using weirs or hook-and-line gear and abundance was estimated using mark-recapture techniques.

At Dickey Lake, 71 steelhead were captured and sampled during spring of 2001 from an estimated spawning abundance of 128 (SE = 27), and 87 steelhead were sampled from an estimated abundance of 115 (SE = 17) in 2002. Ninety-five rainbow trout were captured in 2001, but abundance could not be estimated. In 2002, 190 rainbow trout were sampled from an estimated abundance of 244 (SE = 27). At Hanagita Lake in 2001, 252 steelhead were counted through the weir from an estimated escapement of 338 (SE = 28) in 2001. In 2002, 119 fish were passed upstream between August 31 and September 27. At Hungry Hollow Creek in 2003, 63 steelhead and 81 rainbow trout were sampled.

No genetic differences were observed between steelhead and rainbow trout spawning in the same location (sympatric) in the Gulkana River and they appear to constitute a single population. In contrast, Gulkana River steelhead and rainbow trout spawning approximately 15 km apart (at the outlet of Dickey Lake and in Hungry Hollow Creek) exhibited significant genetic differences and moderate values of F_{ST} (0.022). Finally, the greatest genetic differences were found when Hanagita River steelhead were compared to Gulkana River steelhead and rainbow trout.

The work conducted at Dickey Lake, Hungry Hollow Creek, and Hanagita lakes demonstrated that their respective steelhead populations are relatively small and genetically distinct, and that within the Gulkana River genetic similarities were observed between sympatric spawning aggregations comprised of both life-history forms (steelhead and rainbow trout). Because the contribution of these stocks (both rainbow trout and steelhead) to the total returning steelhead population of the Copper River drainage is unknown, these stocks should be managed conservatively to ensure long-term sustainability in light of existing fishing pressure (commercial interception, subsistence, and sport).

Key words: Abundance, Copper River, genetics, Gulkana River, Hanagita River, life-history, microsatellite, *Oncorhynchus mykiss*, rainbow trout, steelhead, sympatry.

INTRODUCTION

Steelhead *Oncorhynchus mykiss*, the anadromous form of rainbow trout, in the Copper River drainage have the northernmost documented distribution of this species in North America (Burger 1983). Similar to other salmonid species living on the edge of their native range, these populations in the Copper River are thought to be relatively sparse and unproductive (Flebbe 1994).

Adult steelhead migrate to complete their life cycle from North Pacific Ocean through the Gulf of Alaska and up the Copper River (Figure 1) through a commercial fishery near the mouth of the river, as well as through inriver subsistence and sport fisheries before overwintering and spawning in various tributaries. Annual harvests by subsistence fishers, based on reporting from returned fish wheel permits, have ranged from 14-114 fish (ADF&G *Unpublished*). Commercial catches of steelhead are not required to be reported, however given that their run timing overlaps with coho salmon *Oncorhynchus kisutch*, some incidental harvests in the commercial fishery likely occurs. For most areas of the Copper River drainage anglers must release all steelhead caught. Between 1997 and 2001, a total of eight fish were reported harvested by sport fishers

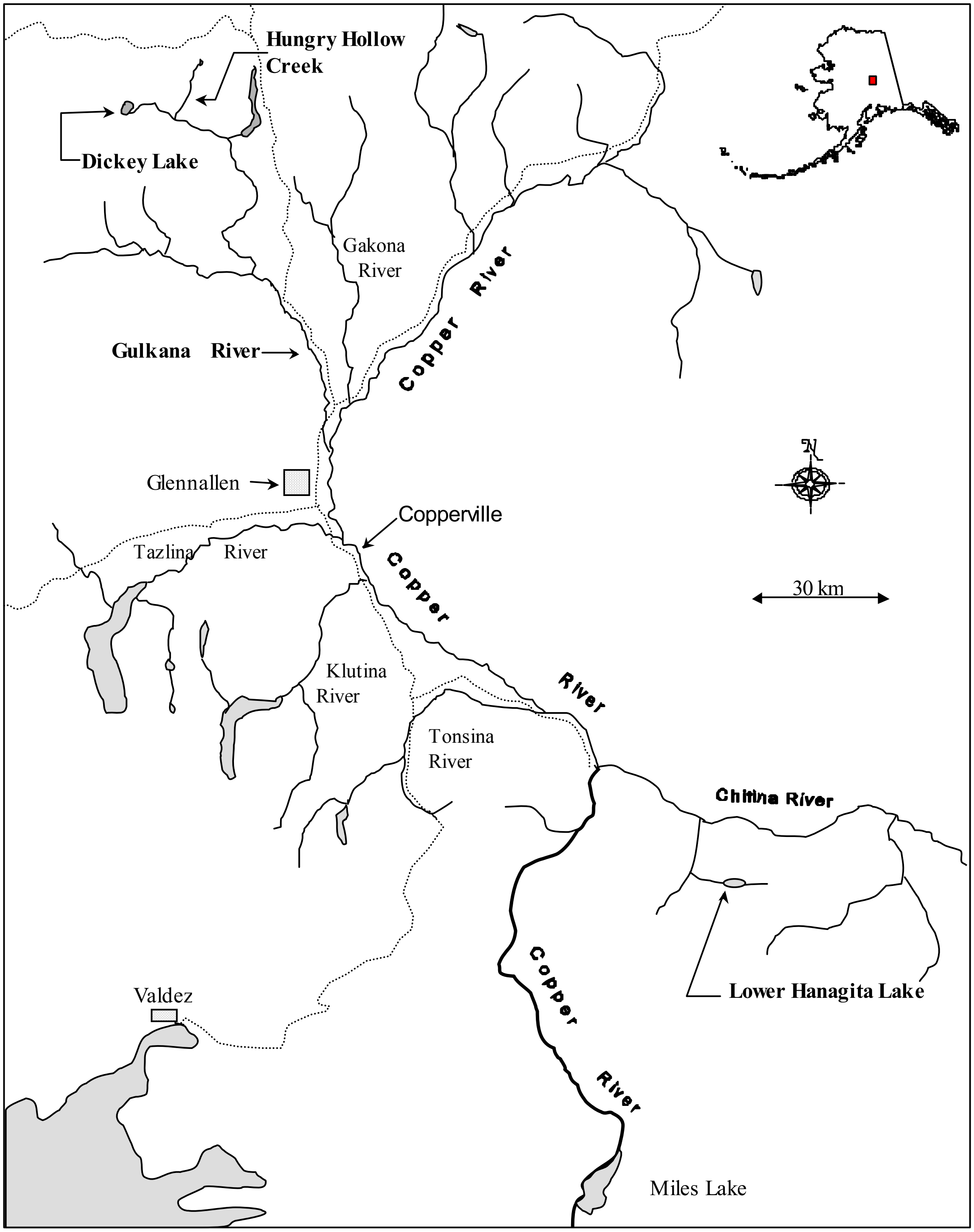

Figure 1.–Copper River drainage with demarcation of study sites, Dickey Lake, Hungry Hollow, and Lower Hanagita Lake.

and during this same period an estimated 213 steelhead were caught and released annually. Hooking mortality on these fish is considered less than 5% (Hooten 1987) given that in most areas artificial lures must be used.

Limited information exists on steelhead in the Copper River, which is attributed to the size and remoteness of the Upper Copper River drainage and their population characteristics (i.e., spawning stock sizes are likely small and seasonally present). Information on Copper River steelhead has been sporadically collected since the 1960s (Williams 1964; Burger et al. 1983; Stark 1999; Brink 1995; Fleming 1999 and 2000). These research efforts have largely been focused on the few known and accessible spawning aggregations upstream of the tagging site in the Copper River drainages, in particular, those spawning near Dickey Lake and Lower Hanagita Lake. In the 1980s steelhead that were captured from the Copper River near Copperville and fitted with radio transmitters led researchers to document a number of spawning locations within the Tazlina and Gulkana drainages (Burger et al. 1983; Williams and Potterville 1985). The largest of these spawning populations was identified at the outlet of Dickey Lake in the headwaters of the Middle Fork Gulkana River. Researchers from the University of Alaska-Fairbanks have conducted studies along the Middle Fork Gulkana River on the steelhead and rainbow trout spawning populations, habitat, and juvenile feeding ecology (Stark 1999; Brink 1995). Beginning in 1998, ADF&G Sport Fish Division has conducted steelhead and rainbow trout research in the Copper River basin in the Tazlina, Hanagita, and Gulkana River drainages (Fleming 1999), which focused primarily on assessment methodologies and seasonal distributions of rainbow trout.

Prior to this study, no reliable information was available that characterized spawning stocks of upper Copper River steelhead in terms of population sizes or genetic population structure. Therefore, the goals of this project (FIS 01-148) were to: 1) gather abundance information on what is currently believed to be the two largest and most significant stocks in the Copper River drainage, the Gulkana (i.e., Dickey Lake) and Hanagita River stocks; and, 2) estimate the degree of relatedness among putative Copper River steelhead populations.

In 2002, goal number two was amended to include an estimation of the degree of relatedness among resident (nonanadromous) rainbow trout and steelhead that occur sympatrically near Dickey Lake and Hungry Hollow Creek. Previous field observations suggested rainbow trout and steelhead in each location may spawn together, forming single populations with both anadromous and nonanadromous individuals (Stark 1999). If true, then the abundance of rainbow trout in these locations must be considered when evaluating the abundance and genetic diversity of steelhead.

This study will provide important information that will help understand population structure and dynamics of Copper River Steelhead thereby improving management of these small populations in light of existing fishing pressure.

OBJECTIVES

Research objectives addressed in 2001 were to:

1. count adult steelhead migrating into spawning areas in the Middle Fork Gulkana, and the Hanagita rivers, that are currently believed to be the most significant spawning stocks in the upper Copper River drainage; and,

2. collect genetic tissue samples from steelhead and rainbow trout at the Dickey Lake and Hanagita spawning areas.

Research objectives addressed in 2002 were to:

1. count adult steelhead migrating into spawning areas in the Middle Fork Gulkana, and the Hanagita rivers, that are currently believed to be the most significant spawning stocks in the upper Copper River drainage;
2. collect genetic tissue samples from steelhead and rainbow trout at the Dickey Lake and Hanagita spawning areas; and,
3. collect genetic tissue samples from Hungry Hollow Creek.

Research objectives in 2003 were to:

1. complete the collection of genetic samples from Hungry Hollow necessary for the final genetic analysis;
2. process the genetic samples collected and conduct final genetic analysis to characterize the population substructure of the Copper River steelhead population(s); and,
3. process previously collected rainbow trout genetic samples to estimate the genetic similarity between the resident and anadromous forms that spawn together at the Dickey Lake and Hungry Hollow Creek spawning areas.

The abundance of rainbow trout in the Dickey Lake spawning area was also estimated in 2001 and 2002 because of the potential interdependence between steelhead trout and rainbow trout in the Gulkana River drainage.

METHODS

STUDY AREAS

Gulkana River

The Gulkana River is a clear, runoff stream that flows southwards out of the Alaska Range approximately 100 mi to the Copper River near Glennallen (Figures 1 and 2). The Gulkana River begins above timberline in Gunn Creek, a tributary to Summit Lake, near Paxson. There are two primary tributaries to the Gulkana River, the West Fork Gulkana River (approximately 185 mi in length) and the Middle Fork Gulkana River (25 mi in length).

Within the Middle Fork Gulkana River (hereafter referred to as the Middle Fork), rainbow trout and steelhead are known to use at least two areas for spawning. Near Dickey Lake (Figure 3) rainbow trout and steelhead use a 2-mile section for spawning that begins approximately one mile downstream of the lake's outlet. Spawning and rearing also occurs in an approximately 8-mile reach of Hungry Hollow Creek. The two areas are notably different. The Middle Fork immediately downstream of Dickey Lake has a moderate gradient, and the river is shallow and runs over a mixture of gravel and small cobble substrates. A unique feature below Dickey Lake is the presence of extensive aufeis accumulations that seasonally cover the river with 6-9 ft of ice. Much of the Gulkana River was described by Albin (1977), more recently by Brink (1995), and later spawning and rearing habitat were examined by Stark (1999).

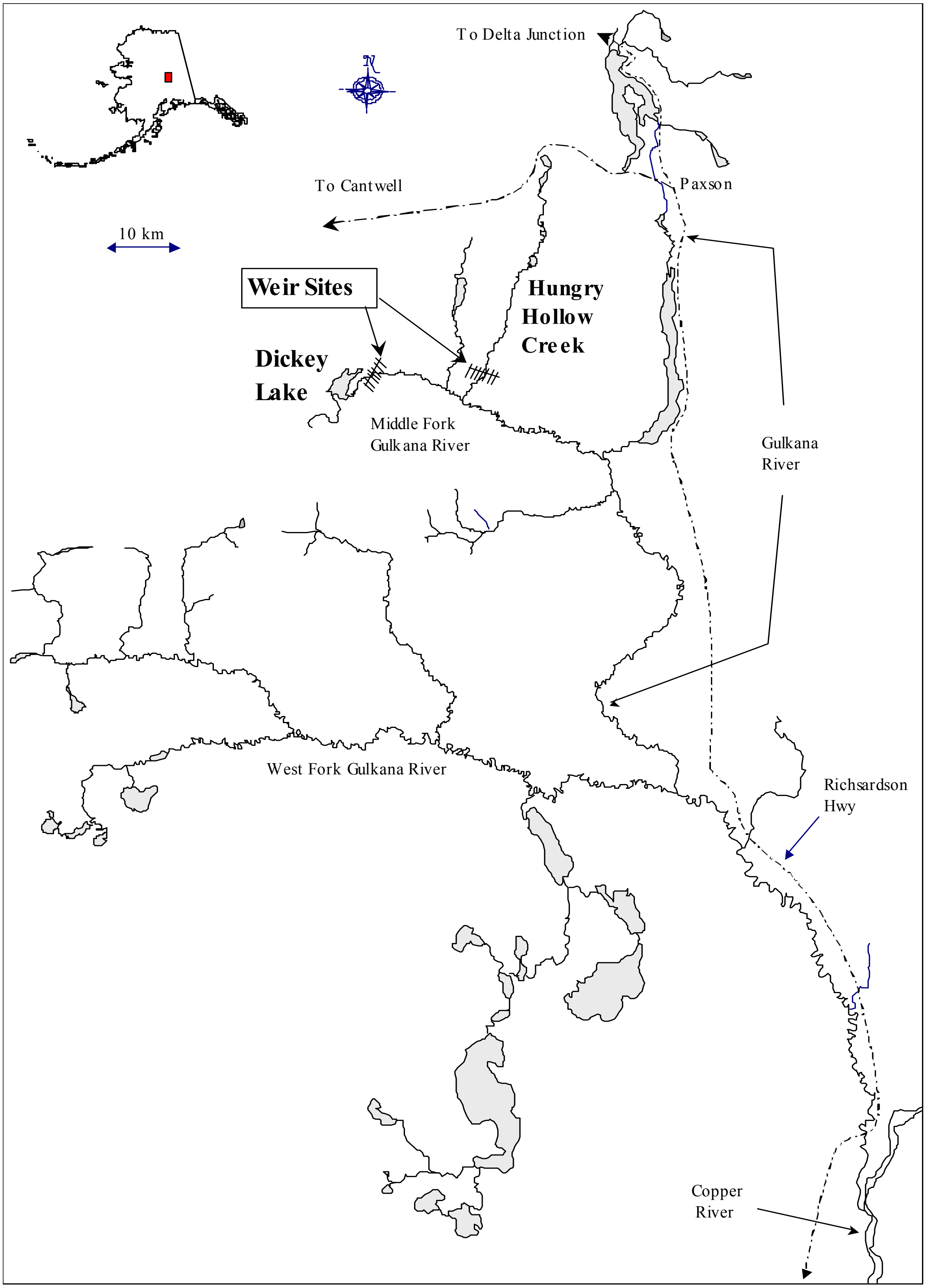

Figure 2.–Gulkana River study areas, 2001 to 2003.

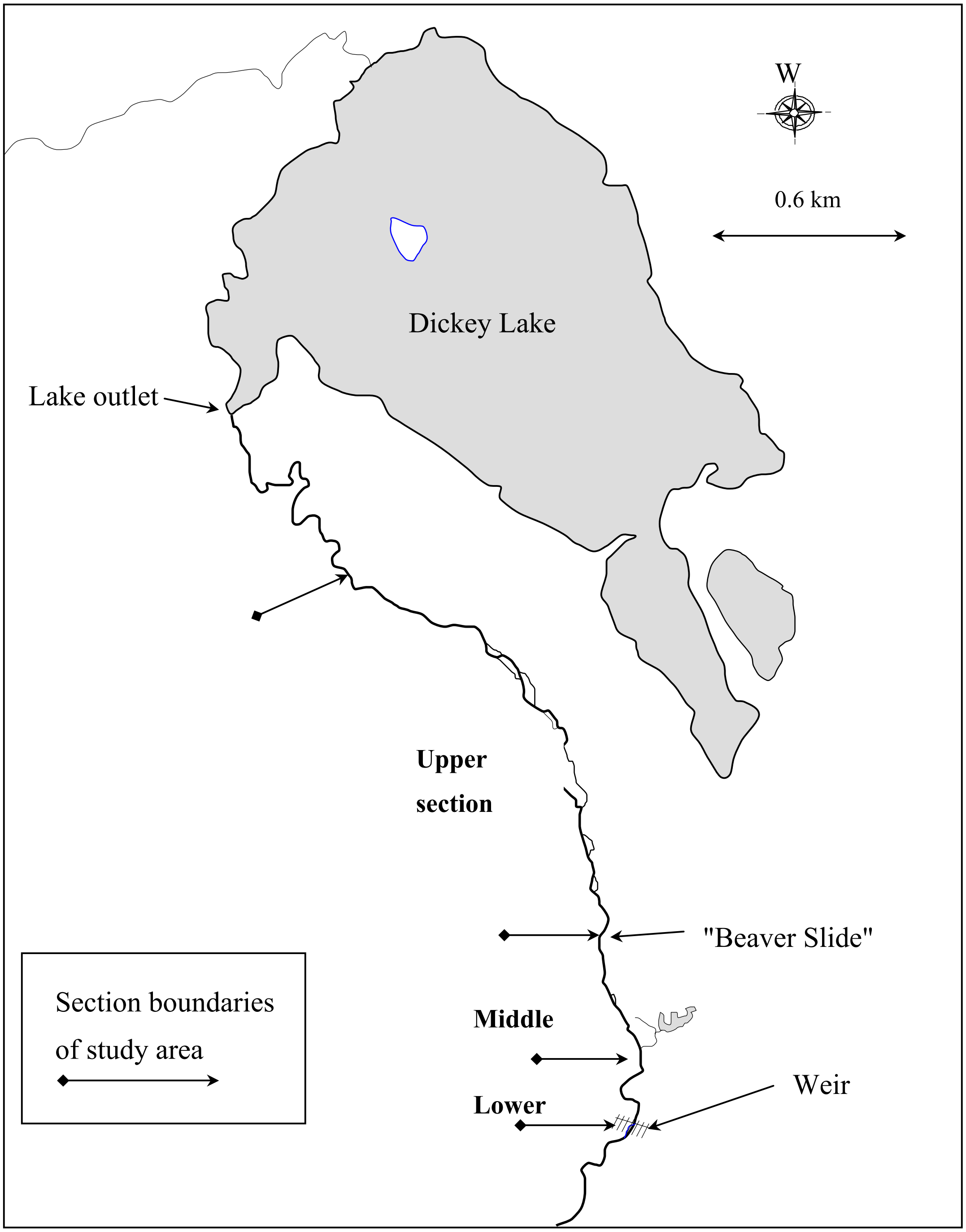

Figure 3.–Dickey Lake study area with upper, middle, and lower section boundaries demarcated, 2001 and 2002**.**

Hungry Hollow Creek runs southward from an area of open tundra near mile 10 of the Denali Highway and drains through a series of small interconnected ponds and lakes before entering the Middle Fork. Below Wait-A-Bit Lake the habitat changes and is primarily composed of large cobble and pool-riffle habitat with a moderately high stream gradient over an 8-mile reach, which is used by spawning and rearing rainbow trout and steelhead. Thick riparian stands of willow *Salix* spp. are the dominant vegetation type mixed with scattered spruce *Picea* spp.

Hanagita River

The headwaters of the Hanagita River drainage include clear and glacial sources that begin on mountain slopes at elevations between 4,000 and 7,000 ft above sea level. The Hanagita River is primarily a clear, run-off river that flows approximately 22 mi through a series of three lakes (Upper, Middle, and Lower Hanagita lakes) from an elevation of 2,800 ft to 2,000 ft (Figure 4). Below the outlet of Lower Hanagita Lake, prespawning steelhead have been observed in the first 1.5 miles below the lake outlet. Most of the drainage below Lower Hanagita Lake is below tree-line with predominately dense willow growth, scattered spruce, and sparse riparian stands of cottonwood trees. In this section the stream gradient was estimated at 55 ft/mi, stream widths range from 30 to 40 ft, and depths range from 2 to 3 ft (Fleming 1999). Stream habitat has been described as predominately pool-riffle habitat with fine gravel substrates in the outlet area of Lower Hanagita Lake. The first 1.5 miles below the lake outlet have been identified as having suitable spawning habitat (Fleming 1999). Below this section, the gradient increases appreciably, the substrate is predominately large cobbles, and the river runs approximately 8.5 mi before joining the Tebay River. The Tebay River runs 10 mi through a steep canyon, with estimates of stream gradients as high as 375 ft/mi, before reaching the Chitina River (Fleming 1999).

Above Lower Hanagita Lake, the river gradually descends from Upper and Middle Hanagita lakes through an open valley composed of wet-muskeg tundra. Immediately upstream of Lower Hanagita Lake, the Hanagita River is a shallow, silty channel for approximately 2 mi. Above this point the stream habitat alternates between a low gradient meandering channel and steeper gradients with intermittent pool-riffle sequences until it reaches Middle Hanagita Lake. Adult prespawning steelhead were observed in this section during a 1998 survey (Fleming 1999).

Most of the drainage below Lower Hanagita Lake is below tree-line with predominately dense willow growth, scattered spruce, and sparse riparian stands of cottonwood trees. Upstream of Lower Hanagita Lake, the vegetation type adjacent to the Hanagita River in the valley bottom is comprised of wet muskeg tundra and mixed stands of willow and spruce abutting adjacent mountain slopes.

ABUNDANCE

Steelhead arrive in the Gulkana and Hanagita River drainages in the fall, overwinter in either lakes or river channels, ascend tributary streams to spawn during spring, and emigrate downstream from spawning areas during late spring and early summer. In the initial project design, weirs with an incorporated video camera were to be used to count the number of steelhead as they migrated to their respective areas. At the Dickey Lake study area, the weir was to enumerate fish (both steelhead and rainbow trout) entering the spawning area during spring, and at Hanagita Lake steelhead migrating to overwintering areas upstream of the outlet of Lower Hanagita Lake were to be counted during fall. However, during the 2001 counting operations at both study areas, it became apparent that complete counts of migrating fish could not be attained,

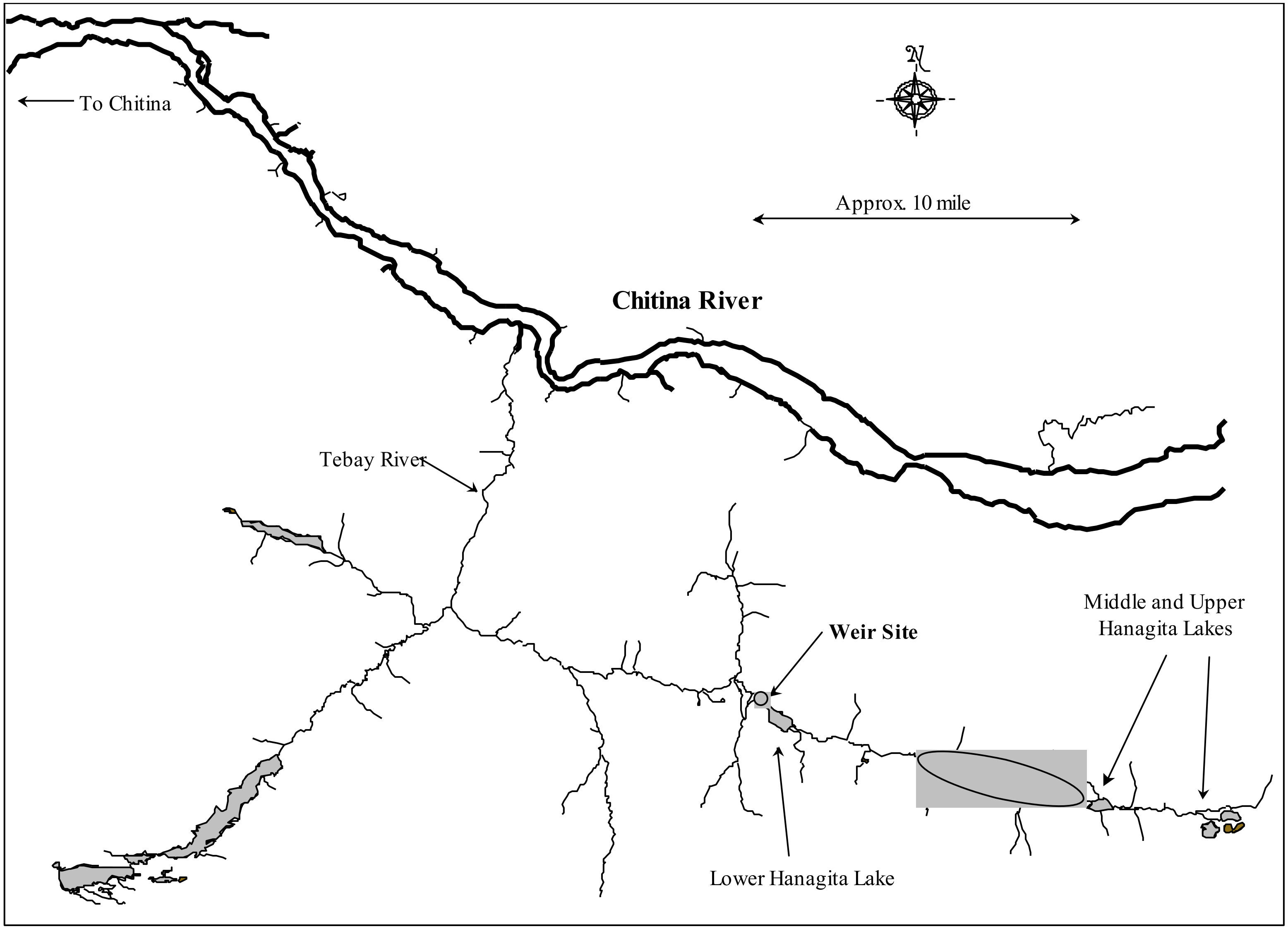

Figure 4.–Map of Hanagita River drainage and weir site. Spawning areas identified in spring of 2002 are represented by shaded areas.

and consequentially, abundance of fish at the Dickey Lake spawning area in 2001 and 2002 as well as the number of fish returning to Lower Hanagita Lake in 2001 were estimated using a two-event mark-recapture techniques.

At Dickey Lake in 2001 for the first (marking) event fish were captured and marked from a two-mile spawning area using hook-and-line gear, and during the second event fish were sampled using a combination of gear, from the spawning area using hook-and-line gear and fish captured in the downstream weir trap as they emigrated from the spawning area. In 2002, fish were solely marked from the spawning area using hook-and-line gear and during the second event fish were captured in a downstream weir trap as they emigrated from the spawning area. In both years, the spawning area was divided into three sampling sections to facilitate the distribution of sampling effort and to provide a minimum scale at which capture probabilities could be examined.

For the Hanagita Lake experiment, fish were marked as they passed upstream through a weir trap erected at the lakes outlet and in a 2-mile reach of stream downstream of the weir site using hook-and-line gear during the fall of 2001. The second event occurred during the spring of 2002 and spawning fish were sampled using a block net and hook-and-line gear. This experiment for the fall of 2002 (first event) and spring of 2003 (second event) was not repeated.

Abundance for each of the five experiments (Dickey Lake steelhead in 2001 and 2002, Dickey Lake rainbow trout in 2001 and 2002, and Hanagita steelhead), was estimated using a two-event Petersen mark-recapture experiment (Seber 1982) designed to satisfy the following assumptions:

1. the population was closed (there was no change in the number or composition of fish in the population during the experiment);
2. all fish had a similar probability of capture in the first event or in the second event, or marked and unmarked steelhead mixed completely between the first and second events;
3. marking of fish in the first event did not affect the probability of capture in the second event;
4. marked fish were identifiable during the second event; and,
5. all marked fish were reported when examined during the second event.

Chapman's modification to the Petersen estimator was used (Seber 1982):

$$\hat{N}_1 = \frac{n_1(n_2+1)}{m_2+1}; \tag{1}$$

where

n_1 = the number of fish marked and released alive during the first event;

n_2 = the number of fish examined for marks during the second event;

m_2 = the number of fish recaptured during the second event; and,

$\hat{N}_1$ = estimated abundance of fish during the first event.

Variance was estimated as:

$$\hat{V}[\hat{N}_1] = \frac{n_1^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}. \quad (2)$$

Assumption 1: At the Dickey Lake study area during 2001, closure was assessed with video monitoring while in 2002, the weir ensured constant abundance by preventing emigration and immigration. At Hanagita Lake, closure of the population relative to movement and overwintering mortality during the experiment could not be ensured.

Assumptions 2 and 3**:** Violations of these assumptions relative to size-selective sampling were tested by using two Kolmogorov-Smirnov (K-S) tests (Daniel 1978). There were four possible outcomes of these two tests; either one or both of the samples was biased or neither was biased. Tests and possible adjustments to correct for bias due to size-selective sampling are outlined in Appendix A. To check for differences in capture probability by location, time of capture, sex, or capture gear, χ^2 contingency table analysis (Conover 1980) was performed. For each variable pertaining to the first event capture probabilities, differences were examined by comparing the ratio of marked (m_2) to unmarked (n_2-m_2) fish, and for second event capture probabilities ratios of recaptured (m_2) to not-recaptured (n_1-m_2) fish were compared. All tests were conducted at $\alpha = 0.05$. The use different gear types during each event served to mitigate potential marking-induced effects in behavior (e.g., gear avoidance).

Assumptions 4 and 5: All fish during the first event were double-marked (internal-anchor tag and fin clip) in standardized locations and all fish caught and sampled in the second event were carefully examined.

Site Specific Procedures

Dickey Lake

2001 Steelhead and Rainbow Trout

On May 25, a fixed picket weir was erected at the lower boundary of the Dickey Lake spawning area. The weir was approximately 70 ft in length and constructed of EMT conduit pickets (¾-in diameter), drilled aluminum stringers, and wooden tripod supports (Figure 5). Incorporated into the weir design was a chute that could be operated for the purpose of assessing the effectiveness of underwater videography to enumerate steelhead (Appendix B). If the quality of the video images were sufficient to accurately identify all steelhead passing through the chute, then underwater videography would have been used in subsequent years of the study to enumerate steelhead to allow for bi-directional, unobstructed passage of fishes.

To collect biological data and to assess the accuracy of video counts a trap or "live box" was affixed to the upstream end of the video chute. Steelhead were to swim through the video-chute and into the trap, and once in the trap, the fish were to be physically removed, sampled, and passed upstream.

During May 26 and 27, several fish were observed holding below the weir and appeared to avoid entering the trap. Steelhead were observed swimming into and then back out of the video chute, but not entering the trap. On May 27, trials of the video equipment was to capture footage of fish behavior relative to the trap. Between May 24 and May 29, no fish had been captured in the

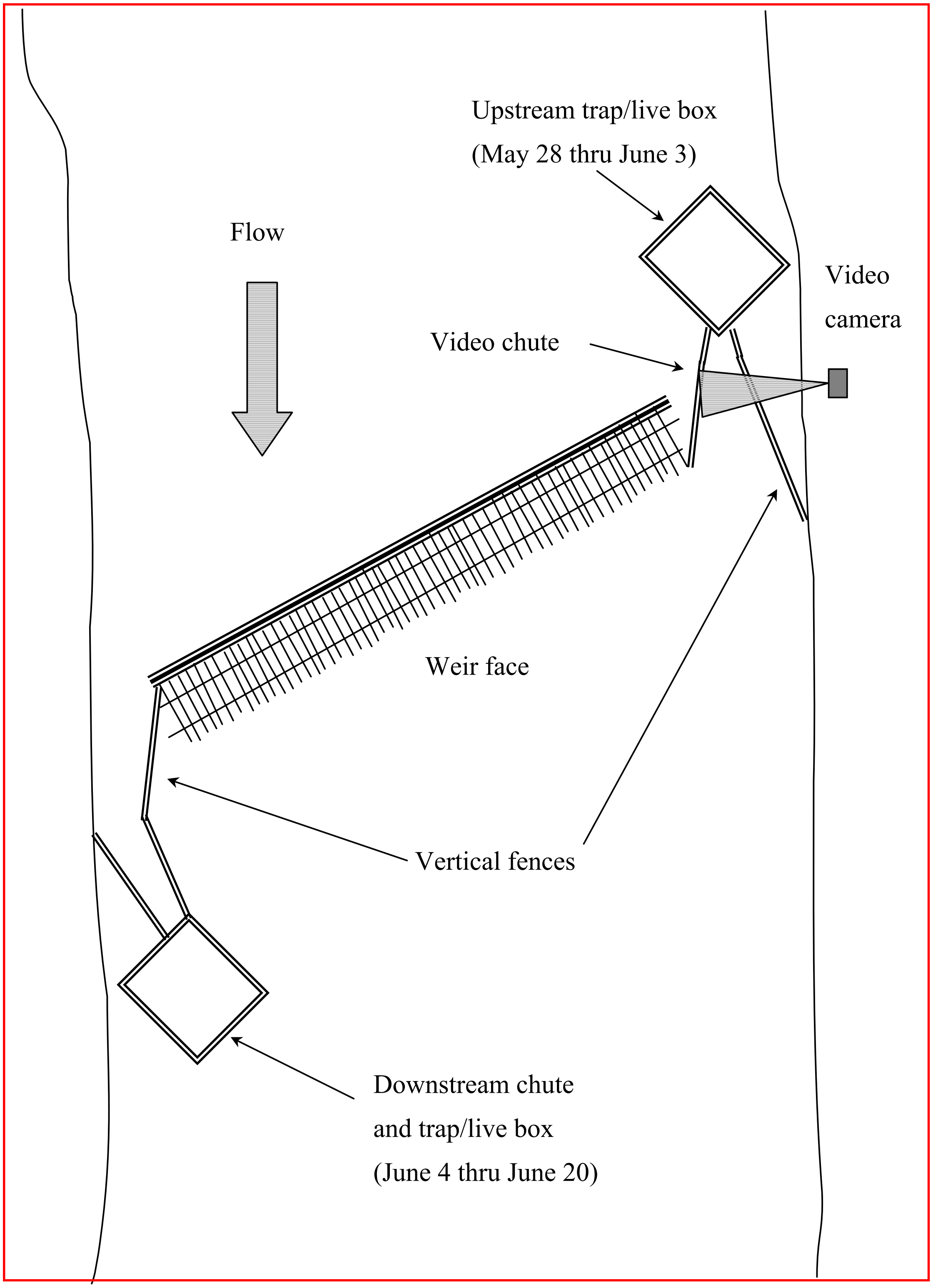

Figure 5.–Schematic of weir configuration used at Dickey Lake in 2001.

trap despite attempts to reconfigure the trap entrance to encourage fish to enter (e.g., shading was added, flow through the trap was increased, and the width of trap entrance was adjusted).

Prior to May 29, it had been assumed that there were no spawning steelhead or rainbow trout upstream of the weir. However, on May 29 a radio-tagged rainbow trout was located upstream of the weir as part of an independent radiotelemetry, and a subsequent foot survey upstream also observed spawning steelhead and rainbow trout. Therefore, complete enumeration of the immigrating spawning population using the weir was not possible and it was decided to estimate the abundance of spawners using mark-recapture techniques. At this point the first (marking) event started (May 29). Using hook-and-line gear, a few of the fish that had been holding below the weir for up to four days were captured, marked, and released below the weir. With the video camera in operation, pickets on the upstream side of the trap were temporarily pulled to allow the holding fish to pass. Video images showed that fish passed during late evening and that same evening, the underwater lighting system failed which precluded further filming during hours of low light.

The first (marking) event occurred from May 29 thru June 9. One to three two-person crews used hook-and-line gear to capture and mark (Floy™ tag and partial fin clip) steelhead and rainbow trout throughout the two-mile long spawning section; for which the upper bound was approximately 1-mi downstream of Dickey Lake. Most of the sampling effort was conducted between June 1 and 3 when three crews were available. Three sampling sections were demarcated (lower, middle, upper; Figure 3) and each sampling day, a crew(s) dispersed to fish different sections of the study area such that the entire area was sampled in a single day or over the course of 2-3 days. During the first event we attempted to subject all fish to similar capture probabilities, which was facilitated by the clear and low water conditions and the creation of the three sampling sections. The low water conditions allowed us to determine where fish densities were the highest and to distribute our effort accordingly. Dividing the study area into three sections helped to budget sampling time evenly throughout the entire study area.

During most of the first event, the video chute and upstream trap remained open during daylight hours to allow upstream passage of fish. From May 30 thru June 1, the video chute and trap were closed and no fish were allowed to pass upstream. On June 2, portions of the upstream trap were dismantled, which were needed in the construction of the downstream trap, and for the remainder of the experiment the video chute remained open to permit fish passage during peak daylight hours only. During hours of poor lighting the chute was closed using pickets. Whenever the video chute was open, video equipment was operated to record the movement of fish into and out of the study area.

On June 3, the second (recapture) event started and the downstream trap was initially used as the sole method to capture fish. Fish were captured in the trap by allowing the trap to remain open for a period (e.g., overnight), closing the trap entrance in the morning or when fish were observed in the trap, and removing them using dipnets.

On June 8, sockeye salmon arrived at the weir and by the next day relatively large numbers and began passing through the video chute. The sockeye salmon may have affected accurate identification of steelhead or rainbow trout.

By June 15, it become apparent that the downstream trap was ineffective because catches in the trap were very low and a relatively large aggregation of steelhead and rainbow trout had developed in a pool just upstream (approximately 300 ft) of the weir. Because an insufficient number of fish was captured using the downstream trap, the experimental design was adapted to include the use of hook-and-line gear upstream of the weir as a capture method, and was used in conjunction with the downstream trap for the remainder of the experiment. Most of the hook-and-line sampling was conducted in the lowermost sampling section just upstream of the weir with periodic forays upstream to find fish. By June 15, the density of fish above the lowermost sampling section was very low and fish were very difficult to detect.

On June 16, the weir was monitored through the night to determine if fish were avoiding entering the trap or if they were entering the trap and escaping back upstream before the trap was closed in the morning. That night fish were observed backing into the trap for a short period and then swimming abruptly back upstream. Subsequently, the trap was monitored overnight for the remainder of the experiment so that the trap entrance was immediately closed after a fish had backed downstream into the trap. This overnight monitoring of the trap markedly increased capture efficiency.

On June 20, a foot survey of the river was conducted upstream of the weir to the outlet of Dickey Lake to determine if sufficient numbers of fish were still upstream to warrant continuation of the experiment. The water conditions were low and clear and only one fish was observed, which was captured using hook-and-line gear. Therefore, the experiment was terminated and the weir was removed.

2002 Steelhead and Rainbow Trout

Using 2001 study results, several adjustments were made to the experimental design. These included: 1) underwater videography was removed from the experiment; 2) the weir was not erected until completion of the marking event; 3) the downstream trap was redesigned; and, 4) the first and second events did not overlap temporally.

The first event occurred from May 28 to June 3. A six-member crew used hook-and-line gear to capture steelhead and rainbow trout throughout the two-mile long spawning section. The study area was again divided into three sections and the boundaries were identical to those used in 2001. Each sampling day, three crews of two to three persons dispersed to fish different sections such that the entire area was sampled each day. The weir was not installed during the marking event to allow all steelhead uninhibited access to the study area.

By June 3, it was decided that: 1) the upstream migration period was complete; 2) a sufficient number of fish had been marked; and, 3) downstream emigration from the spawning area was imminent. Therefore, after fishing the morning of June 3, the weir and downstream trap were constructed. The weir was left open and fish were allowed to pass through until the morning of June 4, at which time the weir was completely closed, and it remained closed for the remainder of the experiment.

The 2002 weir differed from the 2001 weir in that it was: 1) erected perpendicular to shore, 2) no chutes or gates were incorporated into the weir face; and, 3) the trap was separate and placed upstream from the weir (Figure 6). The funnel-shaped trap was constructed using Vexar fencing (black in color, 4 ft tall, with ¾-in mesh), placed about 100 ft upstream of the weir, and a trap door was placed at the end of the funnel. The Vexar was attached to 5-ft lengths of 5/8-in steel rebar driven into the streambed.

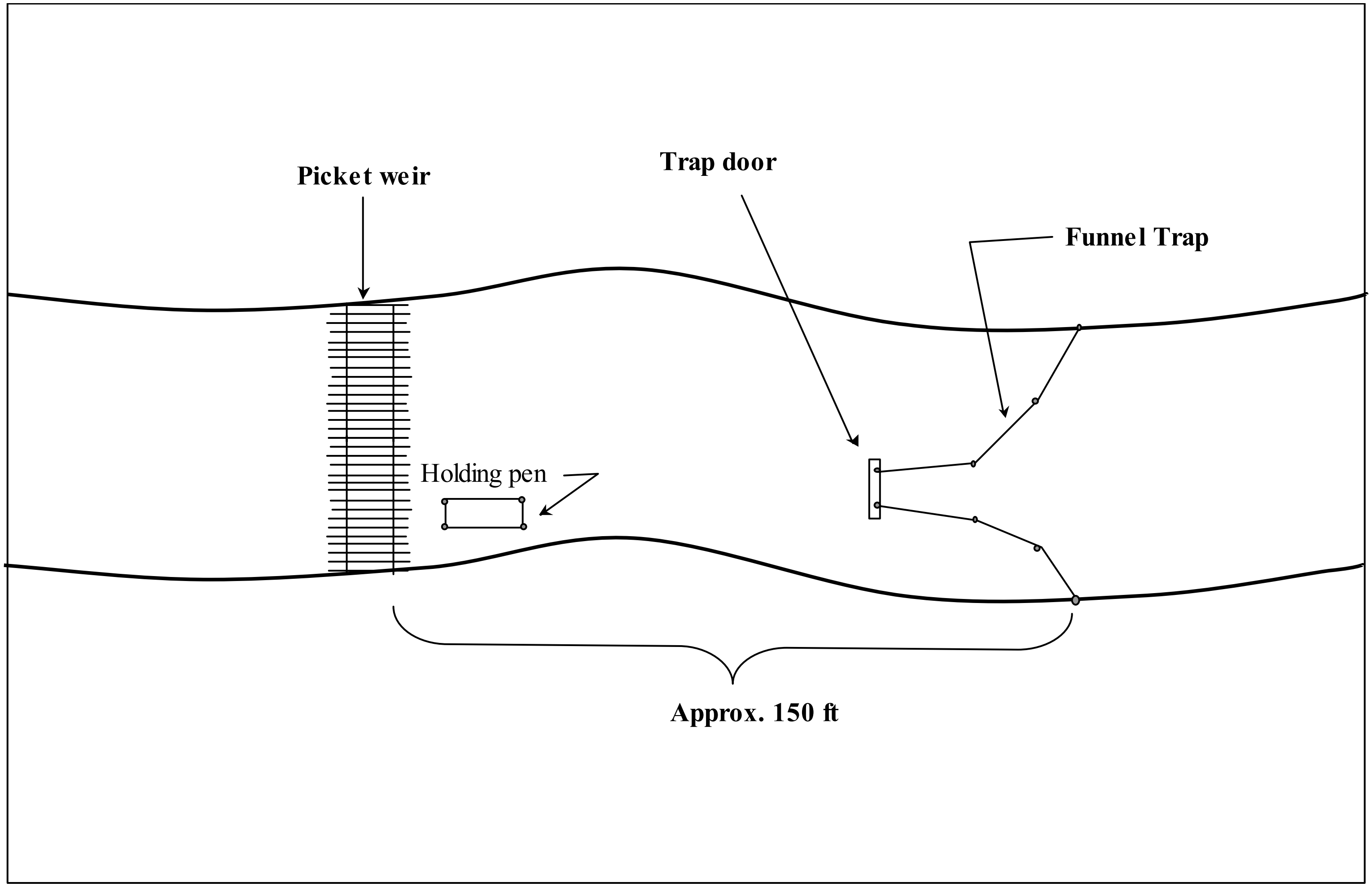

Figure 6.–Schematic of weir and fish trap used on the Middle Fork Gulkana (Dickey Lake) in 2001, both the Middle Fork Gulkana and Hanagita rivers in 2002, and at Hungry Hollow Creek in 2003**.**

The marking event ended with the closure of the weir and the recapture event occurred from June 4 thru June 18. Fish were captured in the trap by leaving the trap open for a 10- to 12-h period, overnight or during the day, and closing the gate using a remote trigger. Fish were removed from the trap using a beach seine and a 3- to 4-person crew. All captured fish were placed in a holding pen, sampled, and carried to the downstream side of the weir where they were released.

During both events in 2001 and 2002, all captured fish were examined for old marks and tags. Sex was determined from external characteristics or from extruded sex products. Fish were identified as a steelhead or rainbow trout; genetic samples (fin clip) were collected and appropriately labeled; capture locations were recorded, and length was measured to the nearest 5 mm for steelhead (FL) and 1 mm for rainbow trout (FL). During the marking event, each fish received an individually-numbered internal-anchor tag (Floy™ FD-94), and given a secondary mark (adipose fin clip). During the second event, unmarked fish were given a lower caudal fin clip to prevent resampling. Steelhead were differentiated from mature rainbow trout using the same criteria as used for the underwater videography.

Lower Hanagita Lake

2001 Weir Operations

On August 29, the weir and trap were erected by 1800 hours. Hook-and-line sampling was conducted in downriver areas on September 2 and 15 to determine if fish were present. On September 27, the weir and trap was removed due to impending icing conditions. During the last two days of weir operations a reach (approximately 2 km) downstream of the weir sight was surveyed to determine if any steelhead still remained below the weir site. Visual observations and hook-and-line sampling were used to measure presence/absence and to gain a rough measure as to how many fish had not migrated past the weir site.

The weir-trap was formed using a fixed-picket weir and a funnel-shaped entrance (Figure 6). The fixed-picket weir was placed approximately 300 ft below the outlet of Lower Hanagita Lake and did not permit fish passage. The funnel-shaped entrance was erected on the downstream side of the weir and was configured with the cone pointed upstream. The entrance was positioned about 180 ft downstream of the weir, and a trap door was placed at the end of the funnel. This door was left open to allow fish to swim into the trap. Twice a day, once in the morning and once in the evening, the trap door was closed and fish were removed from the trap using a beach seine and a three-person crew. Typically, more than one seine haul was required to collect all the fish in the trap, and fish were placed into a holding pen until all in the trap were collected. After sampling, the steelhead were carried to the upstream side of the weir and released, and the trap door was reopened.

All captured steelhead were measured to the nearest 5 mm (FL); examined for old marks and tags; sexed as determined from external characteristics (dimorphism), given an individually-numbered Floy tag and a portion of the lower caudal fin was removed for genetic tissue sample, which also served as a secondary mark.

2002 Weir Operations

On August 28, the weir was erected and was "fish tight" by 1800 hours. On September 27, the weir and trap were removed due to impending inclement weather. Prior to our departure, a 2-mi reach of stream downstream of the weir site was surveyed to determine if any steelhead still remained below the weir site. Visual observations and hook-and-line sampling were used to measure presence/absence and to gain a rough measure as to how any fish had not migrated past the weir site.

2001/2002 Mark-recapture Experiment

On September 27, 2001 steelhead were observed and below the weir site. However, it was unknown what fraction of the run had not passed prior to the weir being dismantled. The number of steelhead remaining below the weir could not be accurately assessed because surface turbulence obscured visibility and there was approximately 8 miles of stream that was not surveyed that could have supported migrating steelhead. There was concern that a substantial portion of the run may not have passed and that the steelhead remaining downstream represented a discrete spawning aggregation. Therefore, a survey of the watershed above the weir the following spring was conducted to with the primary purpose of documenting spawning locations since these were unknown, and secondarily to determine approximately what proportion of the run had not passed the weir by estimating the total run size by examining the proportion of spawning fish bearing marks (Floy tags or fin clips) from the previous fall.

To attain an unbiased estimate of total run size during the fall of 2001), a two-event mark–recapture analysis was conducted where the first event consisted of all fish marked during the fall of 2001 and the second event consisted of all fish examined during the spring of 2002.

On May 28, 2002, a three-person crew was flown into Middle Hanagita Lake – the day after the lake became ice-free. The upper portion of the Hanagita River was surveyed on foot from May 28 thru June 1, which comprised the second event. The survey started at the outlet of Middle Hanagita Lake and ended approximately 2 mi downstream of Lower Hanagita Lake. Fish were captured by "block-netting" and using hook-and-line gear. The block net was a small-meshed gillnet (approximately 75 ft x 4 ft) constructed of 0.5-in monofilament mesh. When block-netting, one person would walk in the channel to "spook" fish, while the other two persons walked the stream banks on opposite sides when possible. When fish were spotted, the bank crew would position themselves approximately 100-200 ft downstream, typically at the end of a run, and stretch the net across the stream. Once in position, the upstream team member would drive the fish downstream into the block net, and as the fish hit the net, the lead and float lines were quickly lifted thereby scooping the fish from the water. Angling and block-netting in combination permitted a systematic and thorough survey of the study area. When wading in the stream, spawning beds were avoided. Block netting was not conducted below Lower Hanagita Lake because the river was too large. All fish sampled were given a lower caudal fin clip to prevent resampling.

GENETICS

Collection of Tissue Samples

During 2001, genetic tissue samples were collected from all fish captured using methods previously described at both the Dickey Lake (steelhead and rainbow trout) and Hanagita (steelhead only) study areas. In 2002, tissue samples were collected only from all fish captured at the Dickey Lake study area – none from the Hanagita study area.

During 2003, genetic tissue samples were collected from steelhead and rainbow trout captured from Hungry Hollow Creek as they emigrated from upriver spawning areas using a fixed-picket weir. The weir was operated by a four-person crew from May 30 to the end of the outmigration period on June 17. The same weir-trap configuration used at Dickey and Lower Hanagita lakes was employed (Figure 6). The fixed-picket weir was placed on Hungry Hollow Creek approximately 1.5 rivermiles upstream from its confluence with the Middle Fork Gulkana River (N62^o 55.25', W145^o 52.41'). Twice a day, once in the morning and once in the evening, the trap door was closed and fish were removed from the trap using a beach seine and a three-person crew. These fish were placed into a holding pen until all fish were collected. After sampling, the fish were carried to the downstream side of the weir and released, and the trap door was reopened. All captured steelhead and rainbow trout were: measured to the nearest 5 mm (mm FL); examined for old marks and tags, and sexed as determined from external characteristics and the presence of sex products. All data and field observations were recorded into field notebooks. Lower caudal fin clips were collected for genetic tissue samples and to identify fish previously sampled.

All fin tissue samples collected from steelhead and rainbow trout were placed in 2 ml sample vials and preserved in 100% ethanol for storage until preparation for genotyping.

Sample Preparation and Genotyping

Thirteen microsatellite loci were used to estimate genetic variation and test for genetic differentiation in Copper River steelhead and rainbow trout (*Ogo1*, and *Ogo4.2*, Olsen et al. 1998; *OMM1322*, and *OMM1325*, Palti et al. 2002; *Omy27*, Heath et al. 2001; *Omy325*, O'Connell et al. 1997; *One8*, *One11*, and *One14*, Scribner et al. 1996; *One101*, *One108*, and *One114*, Olsen et al. 2000; *Ots3.2*, Banks et al. 1999). Total genomic DNA was isolated from approximately 10-20mg of fin tissue using the Qiagen 96-well Dneasy® procedure. Isolated DNA was quantified using a 96-well Packard FluoroCount® Microplate Fluorometer and diluted to 30ng/µl for use in PCR. PCR reactions were conducted in 10 µl volumes consisting of 0.06 units of Taq polymerase, 1µl of 30ng DNA, 1.5-2.5mM $MgCl_2$, 1mM 10x buffer, .8mM dNTP's, 0.006-0.065µM of labeled forward primer (depending on the locus), 0.4µM unlabeled forward primer, 0.4µM unlabeled reverse primer, deionized H_2O, and 1M Betaine (majority of loci). PCR was completed on an MJResearch™ DNA Engine™ PCT-200 or a DNA Engine Tetrad™ PCT-225. The amplification profile consisted of one cycle of 2 min @ 92°C, 30 cycles of 15 sec @ 92°C, 15 sec @ 52-60°C (depending on the locus) and 30 sec @ 72°C, and a final extension for 10 min @ 72°C. Microsatellites were separated on 64-well denaturing polyacrylamide gels utilizing Li-Cor IR^2 scanners and Li-Cor 50-350 or 50-700 bp size standards loaded in lanes 1, 16, 32, 48 and 64. Positive controls, consisting of known genotypes were loaded in four lanes spread evenly throughout each gel to ensure consistency of allele scores. Microsatellites were referenced to size standards and genotypes were scored using Saga™ GT ver. 3.1 (Lincoln, NE) software. Multi-locus microsatellite genotypes were stored in an Excel™ (Microsoft) spreadsheet for data analysis.

Analysis

Genetic Diversity Within Populations

Standard measures of genetic variation including the number of alleles per microsatellite locus (*A*), and the observed and expected heterozygosity (H_O, H_E) were computed for each population sample of steelhead and rainbow trout using the computer program FSTAT version 2.9.3 (Goudet 2001).

A randomization test was used to test for conformity to Hardy-Weinberg equilibrium (HWE) for each locus and population combination (Goudet 2001). For this test, multiple estimates of the statistic *f* were generated by permuting alleles among individuals within each sample. The *P*-value was estimated as the proportion of randomized data sets having a larger value of *f* than the observed data set.

Genetic Diversity Among Populations

Two methods were used to evaluate the influence of geographic location and migratory type (anadromy and nonanadromy) on the population structure of steelhead and rainbow trout in the Copper River. First, a *G*-test of genotypic frequency homogeneity was used to test for genetic differentiation among all possible population pairs (FSTAT version 2.9.3, Goudet 2001). Second, estimates of the degree of population divergence based on the relative measure, F_{ST}, were computed for all possible population pairs according to Weir and Cockerham (1984).

Dispersal Among Gulkana River Populations

Four tests were performed to evaluate the influence of the two migratory types on genetic differentiation between the two steelhead/rainbow trout aggregations sampled in the Middle Fork Gulkana River (the outlet of Dickey Lake and Hungry Hollow Creek). The nonparametric tests used a randomization method to evaluate four statistics and test for differences in gene flow (dispersal bias) based on a trait (e.g., sex, migratory type). The four statistics are mean assignment index (*mAlc*), variance of *Alc* (*vAlc*), F_{ST}, and F_{IS}. (FSTAT version 2.9.3, Goudet 2001). For each statistic the null hypothesis is that the value does not differ between individuals exhibiting different traits.

RESULTS

DICKEY LAKE ABUNDANCE

2001 Steelhead

During 2001, a total of 71 steelhead were captured and sampled. Twenty-eight fish were sampled during the first event and 43 during the second event (Table 1). Nine marked fish were recaptured in the second event. The smallest steelhead captured in the first event was 510 mm FL, the smallest in the second event was 510 mm, and the smallest recaptured fish was 655 mm FL.

Of the 28 fish captured during the first event, 8 were males, 19 were females, and the sex of one fish could not be determined. The lengths of fish from both events ranged from 510 to 840 FL (Appendix C1).

During the experiment, 28 steelhead and 28 rainbow trout were recorded using the video equipment moving into the study area (Table 2). Also, 63 unidentified fish, which were either rainbow trout or steelhead, were recorded swimming upstream past the video camera.

Evidence from the experiment suggested that the population was closed. Although several unidentified fish (either steelhead or rainbow trout) were recorded moving into and out of the study area after June 9, evidence strongly suggested that the immigration of steelhead was over by June 9 or earlier because: 1) in 2001, none of the fish that were positively identified after June 9 were steelhead (i.e., all were rainbow trout); 2) in 2002, no steelhead were observed attempting to move into the Dickey Lake study area after June 3; and, 3) in 2003, no steelhead were observed attempting to migrate upstream of the weir at Hungry Hollow after May 28.

Table 1.–Summary statistics used to assess the assumptions of equal probability of capture by gender, location, time, and gear type for steelhead in Dickey Lake during 2001.

Strata	Number Marked (n_1)	Number Examined (n_2)	Number Recaptured (m_2)	$P_{capture}$ 1st Event (m_2/n_2)	$P_{capture}$ 2nd Event (m_2/n_1)
Sex					
M	8	17	3	0.18	0.38
F	19[a]	25[a]	6	0.24	0.31
Geographic					
Upper	9	_[b]	4	–	0.44
Middle	3	–	0	–	0
Lower	16	–	5	–	0.31
Time (1st event)					
May 28 to 31	5	–	3	–	0.60
June 1 to 4	20	–	5	–	0.25
June 7 to 9	3	–	1	–	0.33
Time (2nd event)					
June 6 to 16	–	27	3	0.11	–
June 17 to 20	–	16	6	0.38	–
Gear					
H&L	–	24	4	–	–
Weir-trap	–	19	5	–	–
Pooled	**28**	**43**	**9**	**0.21**	**0.32**

[a] Discrepancy in numbers of fish between pooled strata and individual strata indicates missing data.

[b] En dash (–) indicates data not available or not pertinent to assumption testing.

Table 2.–Video recording times and video counts of fish (steelhead, rainbow trout, "undecided", and sockeye salmon) passing through video chute. An undecided fish was one that appeared to be a rainbow trout or steelhead but image quality was too poor for accurate identification.

	Video Recording Time			Rainbow Trout			Steelhead			Rainbow Trout or Steelhead			Sockeye
Date	Start Time	Stop Time	Time Elapsed (h)	Counted Up	Counted Down	Net Count	Counted Up	Counted Down	Net Count	Counted Up	Counted Down	Net Count	Up
29-May	19:00	23:59	4:59	1	-1	0	5	0	5	2	0	2	0
30-May[a]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31-May[a]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1-June[a]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2-June	7:55	16:15	8:20	22	-4	18	21	-4	17	0	0	0	0
3-June	14:22	21:00	6:38	0	0	0	5	0	5	19	-5	14	0
4-June	16:00	21:15	5:15	2	0	2	0	0	0	15	-2	13	0
5-June	14:00	21:16	7:16	3	-2	1	0	0	0	14	-2	12	0
6-June	13:15	21:20	8:05	2	0	2	0	0	0	3	--1	2	0
7-June	14:20	21:45	7:25	5	-3	2	3	-2	1	7	3	4	0
8-June	12:30	20:12	7:42	4	0	4	1	-1	0	5	-1	4	12
9-June	14:20	21:10	6:50	1	0	1	0	0	0	2	0	2	126
10-June	10:00	21:24	11:24	1	0	1	0	0	0	2	0	2	149
11-June	10:30	16:37	6:07	0	0	0	0	0	0	0	0	0	92
12-June	9:15	21:30	12:15	0	-1	-1	0	0	0	1	0	1	194
13-June	9:26	21:45	12:19	0	0	0	0	0	0	0	0	0	401
14-June	7:11	13:30	6:19	3	2	1	0	0	0	0	0	0	9
15-June	11:30	23:00	11:30	2	0	2	0	0	0	0	0	0	51
16-June	11:55	23:46	11:51	1	-5	-4	0	0	0	9	-3	6	89
17-June	10:10	22:35	12:25	2	-4	-2	0	0	0	1	0	1	321
18-June	12:55	20:50	7:55	1	0	1	0	0	0	0	0	0	107
19-June	12:03	17:27	5:24	0	0	0	0	0	0	0	0	0	105
Totals				50	-22	28	35	7	28	80	17	63	1,656

[a] From May 30 to June 1, the weir was closed and no video footage was recorded.
nd = no data

The sampling design and the results of the testing procedures dictated that stratification by length, sex, geographic sections, or sampling period was not required, and therefore the Chapman-modified Petersen estimator (Seber 1982) was used to estimate abundance. Because of potential movement of fish out of the study area during the first event, the estimate was germane to the first event.

Male and female steelhead had equal probabilities of being captured in the first (χ^2=0.24, P-value = 0.62) and in the second event (χ^2=0.09, P-value = 0.77; Appendix D1 and D2). No significant differences were found between length frequency distributions when comparing fish marked in the first event and fish recaptured in the second event (DN=0.25; P-value=0.77; Figure 7), and comparing fish marked in the first event and all fish captured in the second event (DN=0.11; P-value=0.96; Figure 7).

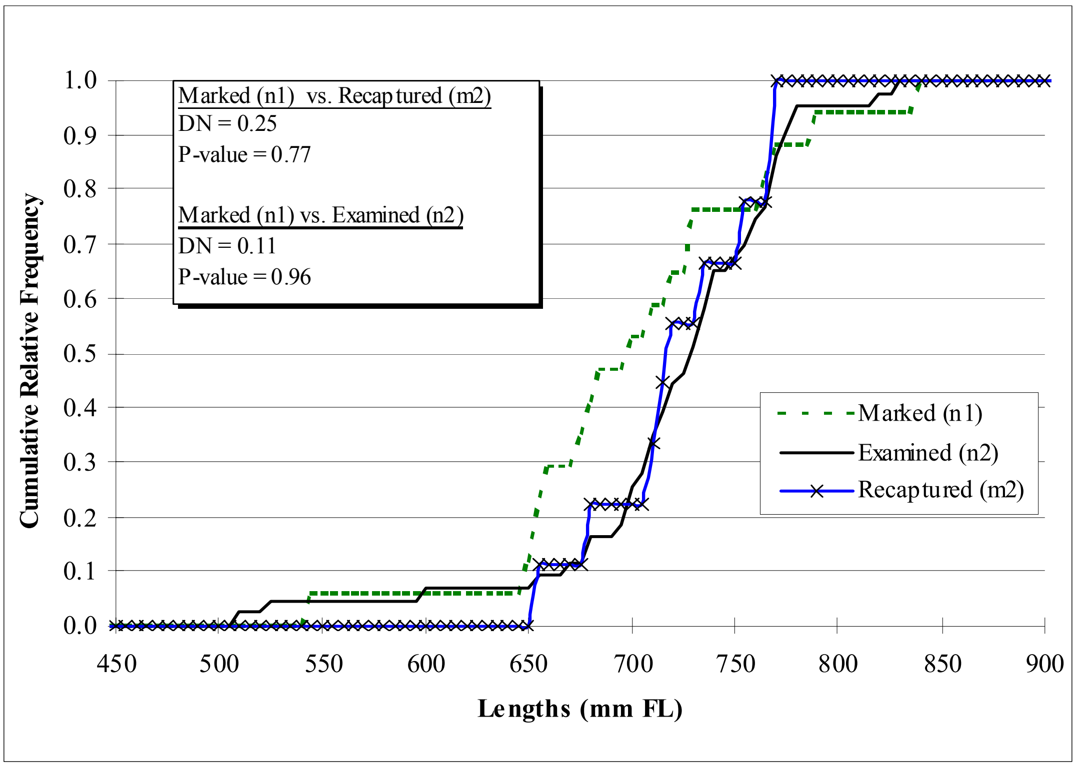

Figure 7.–Cumulative relative frequency distributions for all steelhead marked during the first event, examined during the second event, and recaptured during the second event at the Dickey Lake study area, 2001.

All marked steelhead had equal probabilities of being recaptured in the second event regardless of where marked in the study area (χ^2=2.0, P-value = 0.36; Appendix D3) and when they were marked (χ^2=2.25, P-value = 0.32; Appendix D4). Temporal differences in first event capture probabilities were observed (χ^2=4.23, P-value = 0.04; Appendix D5). Finally, similar capture probabilities were observed during the second event between fish that were captured during the second event using hook-and-line gear and the downstream fish trap (χ^2=0.60, P-value = 0.43; Appendix D6).

The abundance of mature steelhead spawning at the Dickey Lake spawning area during 2001 was estimated at 128 (SE = 27) at the time of the first event.

2001 Rainbow Trout

Thirty-eight (38) fish were marked and sampled during the first event and 43 during the second event. Four marked fish (all males) were recaptured in the second event. The smallest rainbow trout captured in the first event was 190 mm FL, the smallest in the second event was 190 mm, and the smallest recaptured fish was 405 mm FL.

Of the 38 fish captured during the first event, 33 were males, 3 were females, and the sex of two fish could not be determined (Appendix C1). The lengths of all fish captured during both events ranged from 190 to 665 mm FL.

An abundance estimate for mature rainbow trout was not calculated because the experimental design did not satisfy assumptions of the mark-recapture model due to concerns over the lack of closure and poor precision. Significant numbers of rainbow trout immigrated or emigrated during both events of the experiment that resulted in an unacceptable level of potential bias (e.g., 6 to 20%). The results of the rainbow trout sampling did, however, indicate that the order of magnitude of mature rainbow trout at the Dickey Lake spawning area during 2001 was approximately 400 fish.

2002 Steelhead

During 2002, a total of 87 steelhead were captured and sampled. Thirty-nine (39) fish were marked in the first event and 48 were examined for marks in the second event (Table 3). Sixteen marked fish were recaptured in the second event. The smallest steelhead captured in the first event was 460 mm FL, the smallest in the second event was 580 mm, and the smallest recaptured fish was 580 mm FL. Of the 39 fish captured during the first event, 11 were males, 28 were females. The lengths of all fish sampled ranged from 460 to 840 mm FL (Appendix C1).

The sampling design and the results of the testing procedures dictated that stratification by length, sex, sampling sections, or sampling periods was not required. Therefore the Chapman-modified Petersen estimator (Seber 1982) was used to estimate abundance.

Male and female steelhead had equal probabilities of being captured in the first (χ^2=1.17, P-value = 0.28) and in the second event (χ^2=0.12, P-value = 0.72; Appendices C7 and C8). No significant differences were found between length frequency distributions when comparing fish marked (n_1) in the first event and fish recaptured (m_2) in the second event (DN=0.20; P-value=0.70; Figure 8), and comparing fish marked (n_1) in the first event and all fish examined (n_2) in the second event (DN=0.21; P-value=0.23; Figure 8)

Table 3.–Summary statistics used to assess the assumptions of equal probability of capture by gender, location and time for steelhead in Dickey Lake during 2002.

Strata	Number Marked (n_1)	Number Examined (n_2)	Number Recaptured (m_2)	$P_{capture}$ 1st Event (m_2/n_2)	$P_{capture}$ 2nd Event (m_2/n_1)
Sex					
M	11	16	7	0.43	0.45
F	28	32	9	0.28	0.39
Geographic					
Upper	15	_a	8	–	0.46
Middle	19	–	7	–	0.75
Lower	5		1	–	0.63
Time (1st event)					
May 28 to 31	11	–	6	–	0.55
June 1 to 4	14	–	3	–	0.21
June 7 to 9	14	–	7	–	0.50
Time (2nd event)					
June 4 to 8	–	21	5	0.24	–
June 9 to 13	–	16	7	0.44	–
June 14 to 19	–	11	4	0.37	–
Pooled	**39**	**48**	**16**	**0.33**	**0.41**

[a] En dash (–) indicates data not available or not pertinent to assumption testing.

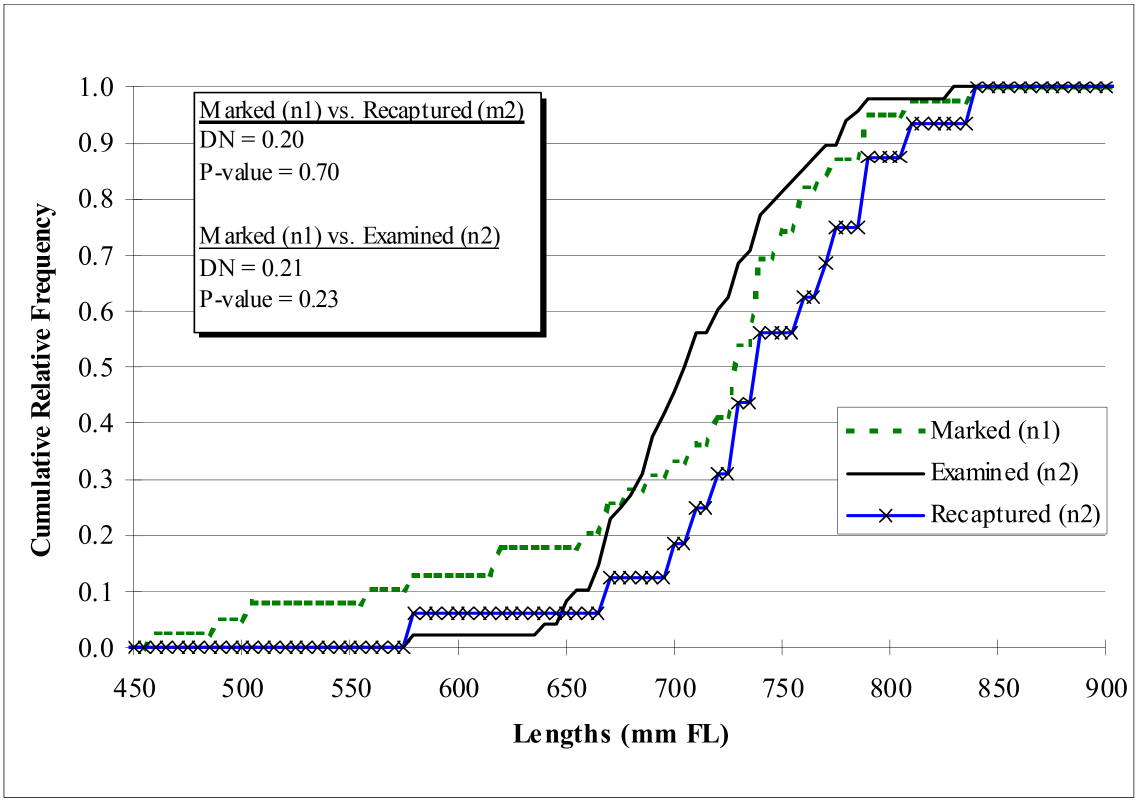

Figure 8.–Cumulative relative frequency distributions for all steelhead marked during the first event, examined during the second event, and recaptured during the second event at the Dickey Lake study area, 2002.

All steelhead had equal probabilities of being captured in the second event regardless of where marked in the study area (χ^2=1.99, P-value = 0.37; Appendix D9) or when they were marked (χ^2=3.52, P-value = 0.17; Appendix D10). Also, no temporal differences were observed in first event first event capture probabilities (χ^2=1.68, P-value = 0.43; Appendix D11).

The abundance of mature steelhead spawning at the Dickey Lake spawning area during 2002 was estimated at 115 (SE = 17).

2002 Rainbow Trout

During 2002, a total of 190 mature rainbow trout were captured and sampled. Thirty-seven (37) fish were marked in the first event and 153 fish were examined for marks in the second event (Table 4). Twenty-three (23) marked fish were recaptured in the second event. The smallest rainbow trout captured in the first event was 260 mm FL, the smallest in the second event was 280 mm, and the smallest recaptured fish was 330 mm FL. Of the 153 fish captured during the second event, 103 were males and 50 were females. The lengths of all fish sampled ranged from 260 to 630 mm FL (Appendix D1).

Table 4.–Summary statistics used to assess the assumptions of equal probability of capture by gender, location and time for rainbow trout in Dickey Lake during 2002.

Strata	Number Marked (n_1)	Number Examined (n_2)	Number Recaptured (m_2)	$P_{capture}$ 1st Event (m_2/n_2)	$P_{capture}$ 2nd Event (m_2/n_1)
Sex					
M	31	103	19	0.18	0.50
F	6	50	4	0.08	0.66
Geographic					
Upper	13	_ a	6	–	0.46
Middle	16	–	12	–	0.75
Lower	8	–	5	–	0.63
Time (1st event)					
May 28 to 31	12	–	7	–	0.58
June 1 to 4	14	–	11	–	0.79
June 7 to 9	11	–	5	–	0.45
Time (2nd event)					
June 4 to 8	–	55	7	0.13	–
June 9 to 13	–	35	4	0.11	–
June 14 to 19	–	63	12	0.19	–
Pooled	**37**	**153**	**23**	**0.15**	**0.62**

[a] En dash (–) indicates data not available or not pertinent to assumption testing.

The sampling design and the results of the testing procedures dictated that stratification by length, sex, sampling sections, or sampling periods was not required. Therefore the Chapman-modified Petersen estimator (Seber 1982) was used to estimate abundance of mature rainbow trout.

Male and female rainbow trout had equal probabilities of being captured in the first (χ^2=2.88, P-value = 0.09) and second events (χ^2=0.06, P-value = 0.80; Appendix D12 and D13). No significant differences were found between length frequency distributions when comparing fish marked (n_1) in the first event and fish recaptured (m_2) in the second event (DN=0.13; P-value=0.94; Figure 9), and comparing fish marked in the first event and all fish examined (n_2) in the second event (DN=0.13; P-value=0.53; Figure 9).

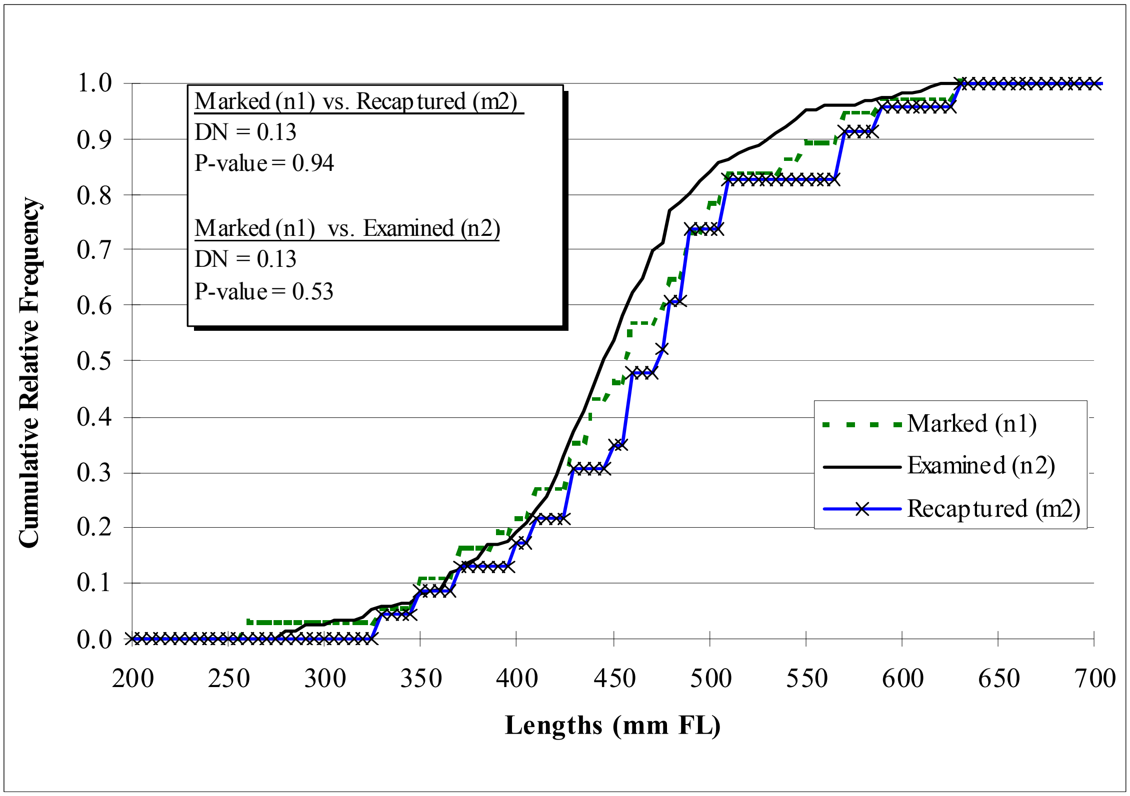

Figure 9.–Cumulative relative frequency distributions for all rainbow trout marked during the first event, examined during the second event, and recaptured during the second event at the Dickey Lake study area, 2002.

All rainbow trout had equal probabilities of being captured in the second event regardless of where they were marked in the study area (χ^2=2.54, P-value = 0.28; Appendix D14) and when they were marked (χ^2=2.98, P-value = 0.23; Appendix D15). Also, no temporal differences were observed in first event capture probabilities (χ^2=1.38, P-value = 0.50; Appendix D16).

The abundance of mature rainbow trout spawning at the Dickey Lake spawning area during 2002 was estimated at 244 (SE = 27).

Lower Hanagita Lake Abundance

2001 (Fall)

Using hook-and-line gear, two steelhead were captured and released approximately 200 m downstream of the weir on September 2, both of which eventually were captured in the weir trap. On September 3, the first steelhead were captured in the weir trap and passed upstream. On September 15, seven fish were captured in downriver areas using hook-and-line gear, and of these, three never entered the trap. From September 3 to 27, a total of 252 steelhead were captured in the trap and passed upstream of the weir (Figure 10). On September 26 and 27, an additional 14 steelhead were captured and sampled using hook-and-line gear downstream of the trap.

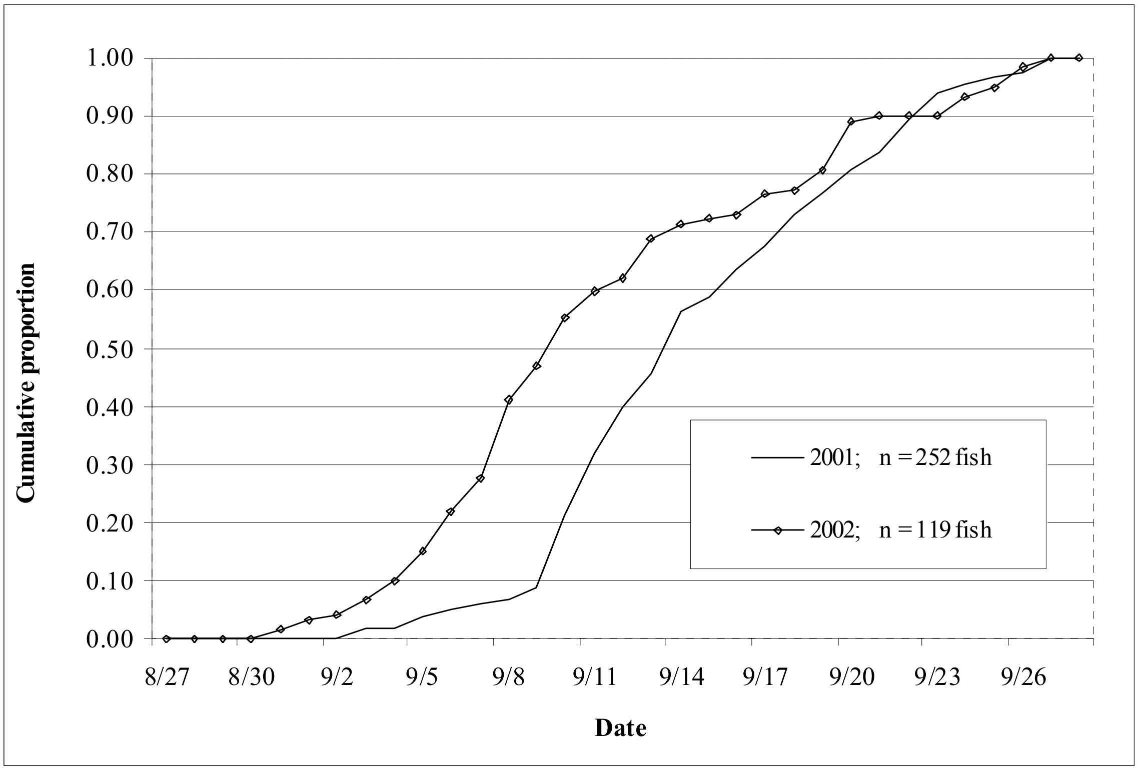

Figure 10.–Cumulative passage of steelhead at the Lower Hanagita Lake weir, 2001 and 2002.

A total of 274 individual steelhead were sampled and lengths ranged from 310 to 890 FL (Appendix C2). Sex was identified for 263 fish, and of these 0.42 were judged to be males (113 males and 159 females). However, due to potential errors in assigning sex well in advance of spawning, these results may not be accurate.

2002 (Spring)

Between May 28 and June 1, 2002, a total of 27 steelhead were sampled: 23 were captured between Middle and Lower Hanagita lakes and 4 below Lower Hanagita Lake (approximately 1 km downstream from the outlet). Eleven females and 16 males were captured.

Spawning activity was observed starting approximately 1 km below the outlet of Upper Hanagita Lake to approximately 1 km below the outlet of Lower Hanagita Lake, with most (>50%) of the spawning occurring in a 2-3 km reach of stream starting approximately 2 km below the outlet of Middle Hanagita Lake. Very few spawning fish or redds (e.g., <10) were observed below Lower Hanagita Lake. No spawning fish or suitable habitat was observed in the lower 4 km reach of river immediately upstream of Lower Hanagita Lake.

The difference in the number of observed spawners above and below Lower Hanagita Lake was related to the observed availability of spawning habitat. Below Middle Hanagita Lake long reaches of suitable substrates were observed, whereas below Lower Hanagita Lake the discharge and gradient were at least twice as large and only a few patches of suitable habitat could be observed along the stream margins. The shore-based survey below Hanagita Lake was not considered a complete survey because of the size and velocity of the stream (e.g. water depth and surface turbulence).

Nineteen fish were sampled that had been sexed in both the fall of 2001 and spring of 2002. Of these, four fish (21%) were females that had been sexed as males during the fall of 2001.

2002 (Fall)

The first steelhead was captured in the weir trap on August 31, 2002, and a total of 119 fish were passed upstream by September 27. During the last seven days of weir operations only 11 fish had passed the weir (Figure 10). The mean size of steelhead sampled at the weir was 675 mm FL and their lengths ranged between 535 to 880 mm FL (Appendix C2).

A total of 20 fish were captured using hook-and-line gear. Six fish were captured on September 15 and 14 fish were captured during the final downriver survey on September 27. On September 27, approximately 30 steelhead were observed in pools in a 6-km section of river immediately downstream of the weir.

Mark-Recapture Experiment

Two-hundred seventy-seven (277) steelhead were marked (n_1) during the fall of 2001. Twenty-seven fish were captured and examined for marks (n_2) during the spring of 2002, and of these 22 were recaptured fish (m_2; Table 5).

Table 5.–Summary statistics used to assess the assumptions of equal probability of capture by gender, location and time for steelhead in Hanagita Lake during fall 2001/spring 2002 experiment.

Strata	Number Marked (n_1)	Number Examined (n_2)	Number Recaptured (m_2)	$P_{capture}$ 1st Event (m_2/n_2)	$P_{capture}$ 2nd Event (m_2/n_1)
Sex[a]					
M	_b	16	14	0.88	–
F	–	10	8	0.80	–
Geographic					
Weir	265	–	21		0.09
Below weir	21	–	1		0.09
Time (1st event)[c]					
Sept. 1 to 14	149	–	13	0.09	–
Sept. 15 to 30	128	–	8	0.07	–
Pooled	**277**	**27**	**22**	**0.81**	**0.08**

[a] Sex for one of the 27 fish examined could not be identified.

[b] En dash (–) indicates data not available or not pertinent to assumption testing.

[c] One recaptured fish did not have an identifiable tag number and was excluded for assumption testing.

The sampling design and the results of the testing procedures dictated that stratification by length, sex, sampling sections, or marking period was not required, and therefore the Chapman-modified Petersen estimator (Seber 1982) be used to estimate abundance.

Male and female steelhead had equal probabilities of being captured in the first (χ^2=0.27, P-value = 0.61; Appendix D17). No significant differences were found between length frequency distributions when comparing fish marked in the first event and fish recaptured in the second event (DN=0.14; P-value=0.88; Figure 11), and comparing fish marked in the first event and all fish captured in the second event (DN=0.14; P-value=0.79; Figure 11).

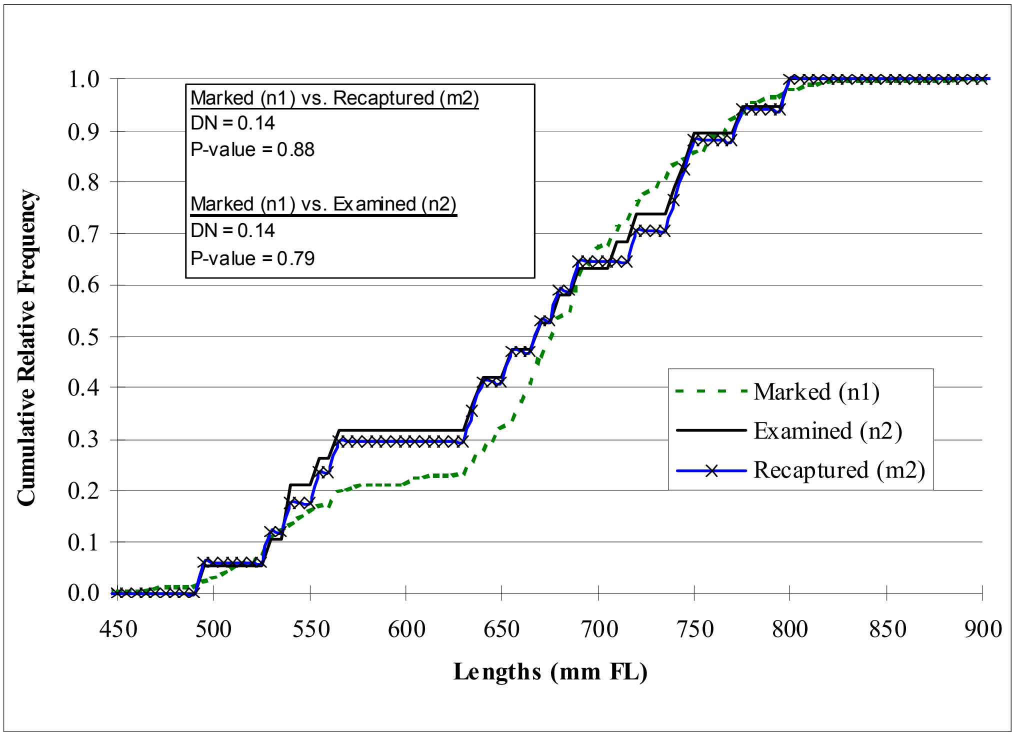

Figure 11.–Cumulative relative frequency distributions for all steelhead marked during the first event (fall 2001), examined on the spawning areas during the second event (spring 2001), and recaptured during the second event at the Hanagita River study area.

All steelhead had equal probabilities of being captured in the second event regardless of whether they were marked at the weir or downstream of the weir (χ^2=0.01, P-value = 0.92; Appendix D18) or if they were marked during the first or second half of the marking event (χ^2=0.627, P-value = 0.43; Appendix D19).

The abundance of mature steelhead that migrated to the Hanagita Lakes spawning area during the fall of 2001 was estimated at 338 (SE = 28). The estimated proportion of the entire run that passed upstream of the weir was 0.81 (SE = 0.08).

HUNGRY HOLLOW CREEK (COLLECTION OF GENETIC SAMPLES)

On May 31, 2003, the first morning the after the weir was constructed, three fish (1 rainbow trout and 2 steelhead) were captured (Figure 12). By the morning of June 17, a total of 144 fish (63 steelhead and 81 rainbow trout) were sampled and passed upstream. The mean size of steelhead sampled at the weir was 685 mm FL and the mean size of the rainbow trout was 450 mm FL (Figure 13; Appendix C3). Genetic tissue samples were collected from all captured fish.

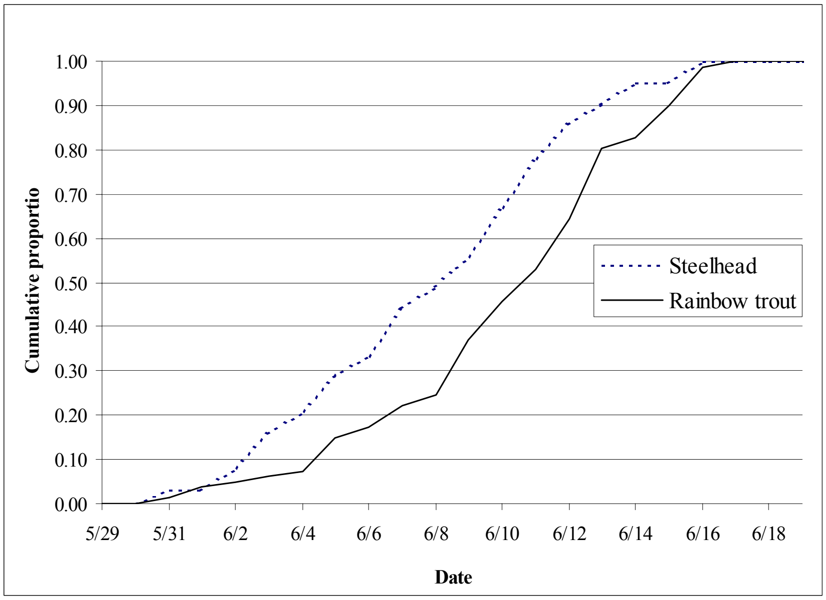

Figure 12.–Cumulative downstream passage of steelhead and rainbow trout at the Hungry Hollow weir trap, 2003.

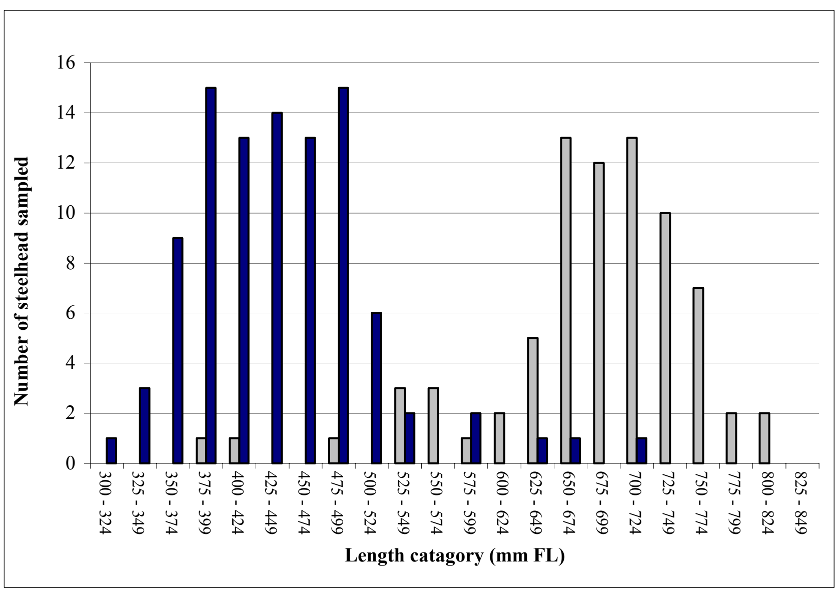

Figure 13.–Length distribution of steelhead and rainbow trout sampled from the weir trap at Hungry Hollow Creek, 2002. Rainbow trout are denoted by dark shading.

GENETICS

Diversity Within Steelhead and Rainbow Trout

A total of 185 steelhead and 184 rainbow trout were collected from Dickey Lake and Hungry Hollow Creek (Table 6). A total of 189 steelhead were collected from Hanagita Lake. Genetic analysis was conducted by genotyping 165 rainbow trout and 220 steelhead (Table 1).

Estimates of the number of alleles per locus and the observed and expected heterozygosity are shown for each sample in Table 7. The average values from the 13 microsatellite loci indicate the degree of genetic diversity is similar for the four samples from the Middle Fork Gulkana River. The genetic diversity of Hanagita River steelhead is lower, but not statistically different, than the steelhead and rainbow trout from the Gulkana River.

Table 6.–Sample sizes for genetic analysis of rainbow trout (RBT) and steelhead (STHD) from three locations in the Copper River.

Location	Type	Year	Collected (n_1)	Genotyped (n_2)
Dickey Lake	RBT	2001	67	67
		2002	37	27
			104	94
	STHD	2001	53	0
		2002	69	64
			122	64
Hungry Hollow Ck	RBT	2003	80	71
Hungry Hollow Ck	STHD	2003	63	60
Hanagita Lake	STHD	2001	189	96
Total			558	385

Table 7.–Genetic variation at 13 microsatellite loci in Copper River steelhead and rainbow trout populations: *n* = sample size, *A* = number of alleles, H_E = expected heterozygosity, H_O = observed heterozygosity. Population abbreviations are Dickey Lake steelhead (DLS), Dickey Lake rainbow trout (DLR), Hungry Hollow Creek steelhead (HHS), Hungry Hollow Creek rainbow trout (HHR), Hanagita Lake steelhead (HNS). An asterisks indicates the single locus H_O is significantly lower (P<0.05) than H_E.

Population	*Ogo 1*	*Ogo 4.2*	*Omy 27*	*Omy 325*	*Om 1,322*	*Om 1,325*	*One 8*	*One 11*	*One 14*	*One 101*	*One 108*	*One 114*	*Ots 3.2*	*Average*
DLS														
n	62	61	64	63	59	62	64	64	64	62	63	64	60	
A	3	4	3	4	6	3	5	3	5	2	8	9	6	4.7
H_E	0.53	0.68	0.31	0.52	0.79	0.49	0.59	0.39	0.78	0.12	0.75	0.85	0.75	0.58
H_O	0.60	0.64	0.34	0.54	0.73	0.60	0.59	0.39	*0.67	0.13	0.68	0.78	0.83	0.58
DLR														
n	93	93	94	94	92	94	94	94	92	86	87	91	94	
A	4	4	4	8	7	4	6	3	5	2	7	10	6	5.4
HE	0.55	0.68	0.31	0.51	0.78	0.50	0.65	0.50	0.75	0.14	0.76	0.80	0.75	0.59
HO	0.54	0.71	0.32	0.50	0.83	0.50	0.69	0.46	0.74	0.13	0.71	0.80	0.78	0.59
HHS														
n	60	60	60	60	59	59	60	60	60	49	60	60	56	
A	4	5	4	5	6	3	4	3	5	2	7	10	5	4.8
HE	0.53	0.68	0.38	0.50	0.79	0.54	0.70	0.38	0.62	0.17	0.79	0.78	0.62	0.58
HO	0.53	0.72	0.38	0.42	0.83	0.59	0.70	0.40	0.63	0.18	0.80	0.77	0.68	0.59
HHR														
n	71	69	71	68	71	71	68	71	70	66	71	70	67	
A	4	4	4	5	5	3	4	3	5	2	8	13	6	5.1
HE	0.54	0.70	0.30	0.61	0.77	0.60	0.71	0.34	0.65	0.17	0.81	0.75	0.58	0.58
HO	0.51	0.75	0.30	0.66	0.76	0.56	0.68	0.34	0.61	0.18	0.82	0.69	0.57	0.57
HNS														
n	96	95	94	96	82	95	96	69	88	79	96	95	94	
A	3	2	3	6	10	3	3	3	3	3	7	10	3	4.5
HE	0.56	0.30	0.52	0.73	0.76	0.63	0.28	0.56	0.60	0.45	0.63	0.61	0.55	0.55
HO	0.56	0.31	0.46	0.70	0.79	0.60	0.29	*0.42	0.59	0.43	0.67	0.58	0.63	0.54

Multiple randomization tests of conformity to Hardy-Weinberg equilibrium for each locus and population revealed 2 tests where the *P*-value for the test statistic *f* was below 0.05 because of a deficit of heterozygotes (Table 8). These results were not common to any one locus or population and were not judged significant when the α-level was adjusted (α/k) for k = 5 tests (each locus across all populations) and k = 13 tests (each population across all loci).

Genetic Diversity Among Steelhead and Rainbow Trout

The results of the *G*-test of genotypic frequency homogeneity and estimates of F_{ST} for all population pairs are summarized in Figure 14. These results indicate there is no genetic difference between steelhead and rainbow trout spawning in the same location (sympatric) in the Gulkana River. In contrast, Gulkana River steelhead and rainbow trout spawning approximately 15 km apart (at the outlet of Dickey Lake and in Hungry Hollow creek) exhibit significant genetic differences and moderate values of F_{ST}. Finally, the greatest genetic differences are found when Hanagita Lake steelhead are compared to Gulkana River steelhead and rainbow trout.

Dispersal Among Gulkana River Populations

Sympatric steelhead and rainbow trout were treated as a single population for this analysis because the tests of genotypic frequency homogeneity indicated they were not genetically distinct. The relative values of each statistic suggest gene flow between the populations spawning in the outlet to Dickey Lake and Hungry Hollow creek is influenced more by the resident rainbow trout than by steelhead (Goudet 2001; Table 8). For example, the *mAlc* was negative for rainbow trout and positive for steelhead, the *vAlc* was larger for rainbow trout than for steelhead, F_{IS} was positive for rainbow trout and negative for steelhead, F_{ST} was smaller for rainbow trout than for steelhead. The randomization tests indicated *vAlc* was significantly larger (*P-value* <0.05) in rainbow trout than in steelhead but the others statistics were not significantly different.

Table 8.–Estimates of mean assignment index (*mAlc*), variance of *Alc* (*vAlc*), F_{ST}, and F_{IS} for steelhead (STHD) and rainbow trout (RBT) from the Dickey Lake outlet and Hungry Hollow creek in the Gulkana River. Randomization test results (*P*-values) indicate the probability that both migratory forms contribute equally to gene flow between the two locations.

	mAlc	*VAlc*	F_{IS}	F_{ST}
STHD	0.295	8.56	-0.0097	0.028
RBT	-0.221	13.30	0.0035	0.019
P-value	0.093	0.012	0.276	0.216

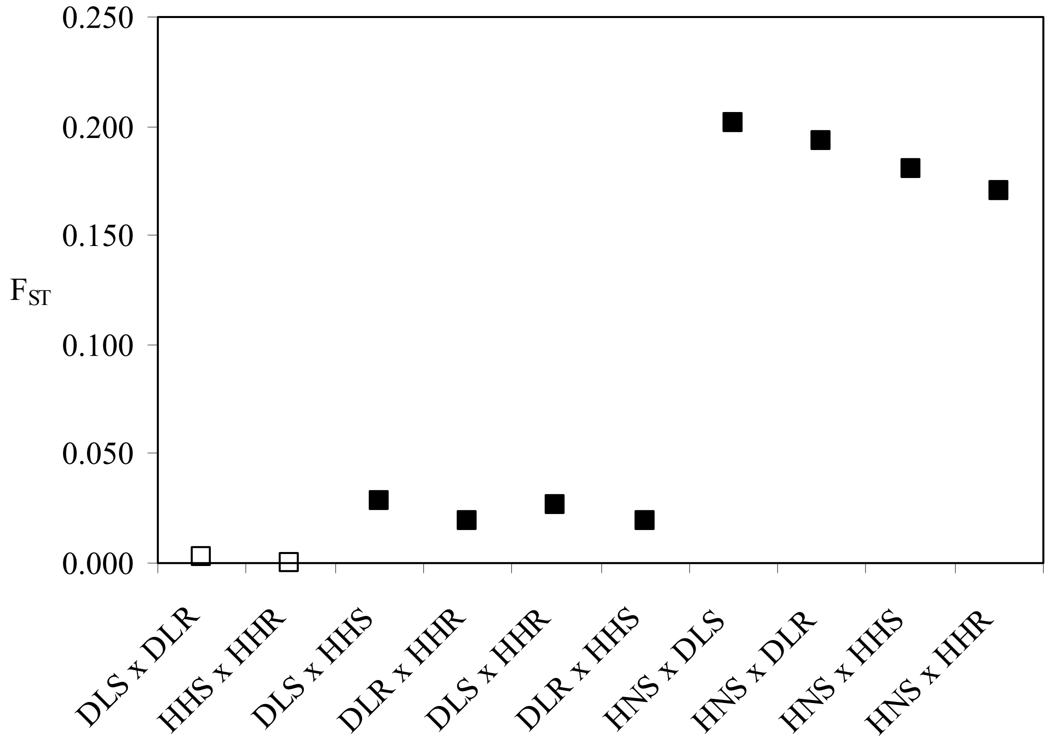

Figure 14.–Estimates of F_{ST} for all population pairs. Black squares (■) denote statistically significant (*P*<0.05) genetic differentiation based on a *G*-test of genotypic frequency homogeneity. Population abbreviations are Dickey Lake steelhead (DLS), Dickey Lake rainbow trout (DLR), Hungry Hollow Creek steelhead (HHS), Hungry Hollow Creek rainbow trout (HHR), Hanagita Lake steelhead (HNS).

DISCUSSION

At both the Dickey and Lower Hanagita lakes study areas, the objective of enumerating all adult steelhead returning to their respective spawning areas using a weir was not achieved. However, the study was successful in attaining estimates of spawning abundance with acceptable levels of precision at Dickey Lake in 2001 (CV=21%), in 2002 (CV=15%), and at Lower Hanagita Lake in 2001 (CV=8%). Although the abundance of rainbow trout could not be estimated in 2001, a relatively precise and unbiased estimate of mature rainbow trout at the Dickey Lake spawning area was attained in 2002 (CV=11%). At Lower Hanagita Lake in 2002, an unknown proportion of the run (>20%) were not passed upstream of the weir. Finally, based on the number of steelhead and rainbow trout captured at the Hungry Hollow Creek weir, their spawning abundance levels are likely similar to the Dickey Lake populations.

DICKEY LAKE

During the 2001 experiment at Dickey Lake, there was a particular concern about violating the assumption of closure that was necessary for attaining an unbiased estimate of abundance. Based on the video footage, there was a relatively large number of unidentified fish, either rainbow trout or steelhead (n = 95) that moved into or out of the study area during the experiment; 73 during the first event and 24 during the second event. More specifically, examination of the video counts showed that up to 15 fish could have immigrated on or after June 9. However, the study results provided strong evidence that none of the unidentified fish passing upstream through the video chute prior to the start of the second event (June 9) in 2001 were steelhead. Of the six radio-tagged steelhead located at the Dickey Lake or Hungry Hollow spawning areas by Burger (1983), all had arrived prior to June 4. Similarly, of the four radio-tagged rainbow trout located at the same spawning areas in 2000, three had arrived prior to May 29, and all had arrived by June 4 (Fleming 2004). Additionally in 2001, no confirmed steelhead were recorded by the video after June 8. In 2002, no steelhead or rainbow trout were observed holding below the Dickey Lake weir after it was closed on June 4, 2002; and similarly in 2003, no fish were observed below the Hungry Hollow weir after May 31. Therefore, the unconfirmed fish were very likely rainbow trout or sockeye salmon and immigration of steelhead onto the spawning grounds was likely complete by June 9 or earlier (e.g., June 4). Therefore, even though not all steelhead were within the study area for the entirety of either event, it is likely that all were within the area for at least some portion of each event and had a non-zero capture probability.

In conducting the mark-recapture experiment at Dickey Lake there were also specific concerns about temporal and geographic differences in capture probabilities resulting from the distribution of sampling effort. Specifically, fish that arrived prior to the start of the first event (early arrivals) would event would have had a higher probability of capture than fish that arrived at some point during the first event (late-arriving). However, during both years of the study, it appears that our method of distributing sampling effort was adequate during the first event (spawning period) as capture probabilities were independent of when and where during the first event fish were marked. This appropriate distribution of sampling effort was largely attributed to the relatively small size of the spawning area (i.e., 2-mile reach), channel topography and water clarity. In general, there were no deep pools (e.g., > 5 ft), the water was very clear, and the stream was easily waded, which aided in determining fish densities and distributing effort accordingly.

At Dickey Lake in 2001, the incomplete weir enumeration of both rainbow trout and steelhead migrating to the spawning area was attributed to planning on installing the weir on May 25 based on the best available knowledge that steelhead and rainbow trout would arrive after this date. Given suitable water conditions, a weir would be an effective means of enumerating the population of rainbow trout and steelhead spawning in the area below Dickey Lake. Telemetry studies of rainbow trout (n=5; Fleming 1999) and steelhead (n=5; Burger 1983) in the Gulkana River suggest these fish likely migrated into the study area from downriver overwintering areas, not from overwintering areas upstream in Dickey Lake. However, in other lotic systems with headwater lakes, rainbow trout (Schwanke 2002) and steelhead (Lough 1983) overwintered in lakes and later moved downstream to spawn. Future assessments such as telemetry studies may be beneficial for testing whether the weir counts are effective at completely enumerating the spawning populations.

At the Dickey Lake study area in 2002, 42% (45 of 115) of the marked steelhead and 63% (153 of 244) of the marked rainbow trout were upstream of the weir when it was pulled. Because of potential identification errors using the video equipment in 2001, it is unclear what proportion of fish remained above the weir when it was removed. The reasons why all fish had not migrated downstream likely included a combination of post-spawning mortality, not leaving the weir in long enough, or weir avoidance. In a similar steelhead study in the Karluk River, survival estimates (ratio of emigrant steelhead to estimated abundance) ranged between 0.36 and 0.67 over a five-year period (Begich 1997). Of the five radio-tagged rainbow trout that spawned at either the Dickey Lake or Hungry Hollow spawning areas in 2001, two did not migrate back downstream to summer feeding areas in the mainstem of the Gulkana River and were presumed dead.

If post-spawning mortality occurred for the fish that failed to pass downstream at Dickey Lake, then it seems reasonable that the onsite crew would have observed carcasses washing onto the weir or along the river during the routine foot surveys. However, no carcasses were observed upstream of the weir in 2001 and no carcasses were observed washing up on the weir during 2001 or 2002. The failure of some fish to move downstream could partially be explained by the hypothesis that fish went upstream into Dickey Lake and did not migrate downstream before the downstream trap was removed (June 20). Fish could have entered the lake to feed. It is also possible that the weir deterred some fish from traveling downstream causing them to remain in the lake or hidden under a cut-bank of the stream until after the weir was removed. Researchers in British Columbia have documented abnormally late outmigrations from some radio-tagged steelhead (Lough 1983), and have suspected weirs or counting fence projects may delay post-spawning outmigrations (Beere 1996). Certainly, some post-spawning mortality occurred at the Dickey Lake spawning area. However, because of weir avoidance and the incomplete duration that the weir was operated, the downstream weir counts should not be used as a measure of post-spawning mortality, but could be used as an index of abundance if it is assumed that the proportion of the spawning abundance which emigrates downstream annually is constant.

HUNGRY HOLLOW

The number of steelhead and rainbow trout enumerated at the Hungry Hollow weir indicated that these spawning populations were similar in population size to those at Dickey Lake. The same factors that resulted in a partial count of out-migrating steelhead and rainbow trout at Dickey Lake were likely applicable to the Hungry Hollow weir. Therefore, assuming that the Hungry Hollow enumerated a similar proportion of the spawning population, then the abundance would have been approximately 150 steelhead and 232 rainbow trout.

Prior to this study, the spawning populations of rainbow trout and steelhead in Hungry Hollow Creek were considered to be smaller (e.g., 50% to 75% smaller) than those at Dickey Lake. This assertion was based on limited telemetric data and limited visual assessments such as foot and aerial surveys. In 1982, twice as many steelhead migrated to Dickey Lake spawning area (n=4) as did to Hungry Hollow (n=2; Burger 1983). Similarly in 2000, four radio-tagged fish were located at the Dickey Lake spawning area and only one in Hungry Hollow Creek. Visual counts of spawning fish (either steelhead or rainbow trout) have been attained at Dickey Lake because the conditions are conducive: little over-hanging vegetation, clear water, and relatively large aggregations of fish spawning over large, broad, and, shallow riffles confined almost exclusively to a 2-mile reach of stream. Visual counts are more difficult to attain in Hungry Hollow because during spawning the water is more turbid, the channel is more incised with a higher gradient, there is large amounts overhanging vegetation, spawning aggregations tend to be small (2-10 fish), and spawning occurs over small isolated pockets of gravel distributed over an approximately 8-mile reach of stream.

HANAGITA LAKE

During both years of the study, the weir-trap at Lower Hanagita Lake did not enumerate the entire upstream migration of steelhead. Possible explanations included a combination of three factors: 1) the run was not over prior to removing the weir; 2) the fish downstream of the weir were already at their overwintering/spawning locations; and, 3) trap avoidance. In both years of the study, the weir-trap was operated for an additional week after 90% of the enumerated fish had already passed upstream, suggesting that the movement of fish was largely over. During both years of the study, a total of 12 fish were captured using hook-and-line gear and tagged in downstream areas during the midpoint of the run (September 15). Only three of these 12 fish were later captured at the weir suggesting that either they were avoiding the trap or were at their overwintering locations. Therefore, it is unlikely that continuing weir operations beyond the end of September would have resulted in enumerating many more (e.g., < 10) fish.

The results of the mark-recapture experiment at Lower Hanagita Lake demonstrated that: 1) spawning location was independent of whether or not it was passed upstream of the weir; and, 2) a substantial proportion (e.g., > 20%) of the steelhead returning in 2002 to the Lower Hanagita Lake study area was not enumerated. During the spring survey of the Hanagita River in 2002, a majority of the spawning occurred downstream of Middle Hanagita Lake, and more importantly, of the four fish that were sampled below the weir site, three had been tagged at the weir and had apparently dropped back downstream at some point during the winter or spring to spawn. Other fish were also observed spawning below the weir site, most of which appeared to have green Floy tags.

Although speculative, it appeared that the proportion of the run not enumerated by the Lower Hanagita Weir in 2002 (≥ 40%) was substantially greater than in 2001 (20%). This conclusion was based on the number of fish observed and sampled using hook-and-line gear in downriver areas immediately prior to pulling the weir during both study years. In 2001, 14 fish were captured out of an estimated 57 fish that had not migrated upriver. Using a similar amount of effort in 2002, a total of 21 fish were captured and at least an additional 30 were counted, which represent a minimum proportion of fish (51/125) not enumerated by the weir. Therefore, the total escapement of steelhead in 2002 was substantially greater (e.g., 200 fish) than was passed upstream of the weir (n = 119).

Incidental to the study objectives, steelhead were examined during 2002 for external body injuries sustained from passing through net fisheries after a relatively high proportion of the sampled steelhead appeared to have marking or injures. Net marks or injuries included: 1) a linear brand or abrasion extending from the leading edge of the dorsal fin down towards the anal fin; 2) linear branding or abrasion in a vertical orientation around the body of the fish, particularly behind the gill plates; 3) tearing or removal of the leading fin rays of the dorsal fin, 4) portions of the upper and lower jaws missing; 5) gill plate damage; and, 6) ripped caudal fins. Of the 122 fish examined for net marks, 34 (28%) appeared to have branding or injuries sustained from net fisheries. Although not mandated at this time, we recommend a system to assess harvest in commercial fisheries – reporting requirements are required for sport and subsistence fisheries.

GENETIC DIVERSITY IN COPPER RIVER STEELHEAD AND RAINBOW TROUT

The genetic data yielded four results that have conservation implications and provide insight into the factors influencing genetic diversity of steelhead and rainbow trout in the Copper River.

First, sympatric groups of steelhead and rainbow trout, such as those found in the Middle Fork Gulkana River, appear to constitute a single population exhibiting partial anadromy, the term describing a single gene pool that displays, or has the potential to display, migratory and resident individuals (Jonsson and Jonsson 1993). This finding supports the initial field observations of spawning between resident and migratory *O. mykiss* (Stark 1999) and suggests that the degree of anadromy in these populations is influenced by the abundance of rainbow trout (and vice versa). Support for this conclusion also comes from the estimates of total abundance and expected heterozygosity (H_E) for Dickey and Hanagita lakes steelhead. The abundance and average H_E estimates for Dickey Lake steelhead in 2002 are 115 and 0.58. The relatively low estimate of abundance is consistent with previous observational data from aerial and ground surveys (Fleming 1999; Stark 1999). The abundance and average H_E estimates for Hanagita Lake steelhead in 2001 are 338 and 0.55. The abundance estimates suggest the Hanagita Lake population is larger than the Dickey Lake population and therefore should have a larger H_E. This is not the case, however. The larger H_E estimate for Dickey Lake steelhead is consistent with the conclusion that this population produces anadromous and nonanadromous forms. For example, the estimate of abundance of Dickey Lake rainbow trout in 2002 was 244, giving a combined estimate (steelhead and rainbow trout) of 359. This combined value is more consistent the estimates of H_E from Dickey and Hanagita lakes. Therefore, conservation and management strategies for *O. mykiss* in the Middle Fork Gulkana River should consider the total abundance of both resident and anadromous forms where they occur in sympatry.

Second, the steelhead and rainbow trout spawning at the outlet of Dickey Lake are genetically different from the steelhead and rainbow trout spawning in Hungry Hollow Creek. The degree of genetic differentiation ($F_{ST} = 0.022$) is relatively large given the short distance (≈ 15 km) between the two spawning groups. This finding suggests migration (gene flow) between these populations is limited and, given the significant differences in spawning and early rearing habitat (Brink 1995; Stark 1999), it is possible that selection may be occurring at adaptively important traits. This evidence of fine-scale population structure demonstrates that of steelhead and rainbow in the Gulkana River drainage be managed conservatively.

Third, genetic diversity among populations is greatest for the populations furthest apart (Middle Fork Gulkana River and Hanagita Lake). This finding, together with the results above, indicates that geographic location, not migratory type, is the major determinant in defining stocks of steelhead or rainbow trout in the Copper River.

Finally, the examination of dispersal (gene flow) between the two populations from the Middle Fork Gulkana River suggest the non-migratory form (rainbow trout) play a greater role in fine-scale gene flow than the migratory form (steelhead). This finding may be explained by the fact that most rainbow trout from the two areas are iteroparous, which may increase the likelihood of straying at least once in a lifetime, whereas most steelhead in the Copper River drainage are semelparous. Moreover, "resident" rainbow trout, while not migrating to the ocean, are highly migratory and do mingle within the lower Gulkana River system before returning to spawn. Tag recoveries and telemetric studies have confirmed extensive migration and intermingling of populations of rainbow trout within the Gulkana River (Stark 1999). The intermixing of Dickey Lake and Hungry Hollow Creek fish may increase the likelihood of some individuals straying when the aggregations return to spawn.

Although the rainbow trout appear to play a greater role in gene flow at a small spatial scale (within the Middle Fork Gulkana River) it is unlikely they play as large a role in broad-scale gene flow. For example, no evidence suggests rainbow trout migrate between the Gulkana River and Hanagita lakes. Therefore, broad-scale gene flow (across distant tributaries) is more likely to result from straying steelhead. The data from this study do not allow a test of this hypothesis; however, it seems prudent to acknowledge the two migratory forms may play geographically distinct roles in the maintenance of genetic diversity and population structure of *O. mykiss* within the Copper River. Management strategies, therefore, should aim to maintain genetic diversity by maintaining the abundance of both steelhead and rainbow trout in the Copper River. Where the two migratory forms occur in sympatry, it is probable that a single population exists and genetic diversity in either form is probably linked to the combined abundance.

CONCLUSIONS AND RECOMMENDATIONS

If future monitoring of the steelhead or rainbow trout populations at Dickey Lake, Lower Hanagita Lake, or Hungry Hollow Creek is warranted, several considerations or study design changes are recommended.

DICKEY LAKE

1) The 2002 study design of the mark-recapture experiment at the Dickey Lake study area was successful and should be repeated to attain an estimate of steelhead and rainbow trout abundance. The experiment was a success because the area was well-suited for a mark-recapture experiment: 1) spawning was confined almost exclusively to a small 2-mile reach of river; and, 2) Dickey Lake buffers stream flow which improves water clarity for angling and decreases the likelihood of the weir washing out.

2) Using a weir to count the immigration of fish to the spawning area is not recommended due to high water caused by snow-melt run off during pre-spawn migrations.

3) Underwater videography is not recommended because: 1) immigration of fish to the spawning grounds can, at a minimum, only be partially enumerated due to high water at break-up; 2) fish identification can be problematic due to poor lighting despite good water clarity, 3) there would be no savings over running a weir because staffing requirements and logistical costs would be similar; 4) risks of equipment failure; and 5) acquiring age, length, and sex information requires fish to be captured.

4) The design of the weir-trap was effective. To minimize trap avoidance or fish backing out of the trap the distance between the funnel-shaped fence and the weir should be maximized (e.g., > 100 ft) while ensuring that seining is still effective. Ideally, a portion of the stream bounded by the trap should also contain some deep-water refugia (e.g., 3-4 ft) for cover. A second trap laterally offset from the first may also help to keep fish from escaping the trap. Finally, because the steelhead tended to move and enter the trap at night, seining should be conducted near sunrise to minimize the probability of fish exiting the trap.

5) Finally, because of selectivity problems using hook-and-line gear, it is recommended that the weir-trap be used to capture fish to attain a representative sample. However, because of potential sex-related differences in migratory timing, the weir-trap should be operated over the entire out-migration period (approximately June 20).

HANAGITA LAKE

1) The use of underwater videography to enumerate steelhead migrating to lower Hanagita Lake is not recommended. Although identification of steelhead would not be problematic at Lower Hanagita Lake, the utility of using underwater videography is still marginal because: equipment reliability is suspect and staffing requirements are similar to what is required with the weir.

2) Moving the weir downstream to intercept fish that by be overwintering in downriver areas is not recommended because no suitable sites are available without using a substantially stronger weir, and if one were deployed, the increase in the number of fish passed would likely be only marginal due to trap avoidance.

3) In both years of the weir operations only a portion of the run was enumerated. To ensure that a greater proportion of the run is enumerated, it is recommended that the same weir-trap design be used and the fish be counted as they pass through a gate in the weir. The trap should be checked frequently, particularly during low light conditions. If age-sex-length sampling is required, periodic seining could be conducted, however fish that cannot be captured after a couple of attempts should be allowed to pass upstream. Finally, the weir should be extended until the onset of freeze-up. These efforts should help to reduce trap avoidance and ensure that most (e.g., >90%) of the fish are passed upstream.

4) If information on total abundance is desired, the mark-recapture experiment should be repeated. To improve the precision for the estimated proportion of run that was passed upstream of the weir, increasing the number steelhead sampled in the spring is recommended. This could be accomplished by focusing effort in the first 5 river miles downstream of Middle Hanagita Lake.

HUNGRY HOLLOW CREEK

1) Based on the number of steelhead and rainbow trout enumerated at the Hungry Hollow Weir, this system may provide an equally reliable index of abundance compared to the Dickey Lake population. The primary advantage of periodically monitoring this population is that it can be accessed using 4-wheelers as opposed to helicopters. If the populations in Hungry Hollow are monitored in the future it is recommended that: 1) the weir be installed immediately following break-up; 2) the weir be strengthened by minimizing spacing between tripods; 3) the weir should be extended onto the banks in the event of high water; and, 4) in the event of rain, the weir should be cleaned frequently (e.g., every hour) to prevent vegetation and debris from clogging the weir face.

2) A mark-recapture experiment similar to the Dickey Lake design would not be feasible because the spawning occurs over a much larger area (approximately 8-mile reach) and representative sampling using hook-and-line sampling gear would be formidable due to difficulties associated with accessing the stream. Most (e.g., 80%) of the stream banks along Hungry Hollow Creek are heavily vegetated with tall (e.g., 6 to 10 ft) mature and dead willow, which makes the stream very challenging to survey and fish. Wading in the stream is also an unrealistic expectation because of the channel topography (frequent deep pools), relatively steep gradient (fast water), and large cobble substrate.

The work conducted at both Dickey and Hanagita lakes demonstrated that the number of fish spawning at these locations is relatively small and their life histories differ by the presence of non-anadromous rainbow trout. If, as has been hypothesized, the Dickey and Hanagita Lake stocks, represent the two most significant stocks of steelhead returning to the Copper River drainage, then the number of fish returning to the Copper River in any given year may be small (e.g., <1,000 fish). However, based on anecdotal information, it is possible that the steelhead return to the Copper River drainage is composed of many smaller-sized spawning populations similar in size to the Hungry Hollow stock, suggesting a return considerably larger than 1,000 fish may exist. In order to assess the relative size of the total spawning population in the Copper River drainage, a radiotelemetry study is recommended that will test the hypothesis that a return larger than 1,000 steelhead exists by estimating the relative contribution of the Dickey and Hanagita lake spawning stocks to the drainage-wide steelhead spawning escapement for two consecutive years. This project will also provide information on: 1) in-river run-timing and distribution, which is necessary to manage and protect overwintering, rearing, migratory, and spawning habitats, and, 2) identify other stocks or populations (e.g., spawning aggregations) that could be used as indices of total run size.

It is also recommended that reporting requirements for the incidental harvest of steelhead in the Copper River commercial salmon be instituted. This information combined with the telemetry study would permit an evaluation of exploitation rates to help ensure the long-term viability of Copper River steelhead.

Because of the apparent genetic interdependence between steelhead and rainbow trout in the Gulkana River system and potential genetic independence among spawning areas, life-history investigations of the resident rainbow trout population in the Gulkana River are recommended. Specifically, documentation and relative importance of significant spawning locations is needed. Telemetric work using only 12 radio-tagged rainbow trout conducted by Fleming (2004) lead to the discovery of one new spawning area, Twelve-mile Creek, where a ground survey identified both spawning rainbow trout and steelhead. A steelhead radiotelemetry study with larger sample sizes (e.g., 120 fish) and with tagging operations positioned downstream of the Chitina River would likely identify all significant spawning areas in the upper Copper River and provide for adequate precision in determining the relative significance (proportional distributions) of the primary spawning areas such as the Dickey Lake spawning area. Investigations that examine the interdependence between resident rainbow trout and steelhead would also be beneficial. For example microbial otolith analysis could determine the maternal status (anadromous vs. non-anadromous) of both rainbow trout and steelhead, and estimating the sex ratio of mature-sized rainbow trout from an internal inspection in the Gulkana River would validate the hypotheses that females tend to exhibit anadromy based on the skewed sex ratios of steelhead and rainbow trout observed at Dickey Lake and Hungry Hollow Creek. Because of potential biases when sampling spawning aggregation, collection of sex information should be collected during autumn.

Because of the apparent genetic interdependence between steelhead and rainbow trout in the Gulkana River system and genetic independence among spawning areas these in the Gulkana river drainage fish should be managed as a single stock. Meaning they should be afforded equal protection to ensure long-term sustainability.

ACKNOWLEDGEMENTS

The U.S. Fish and Wildlife Service, Office of Subsistence Management provided $394,400 in funding support for this project through the Fisheries Resource Monitoring Program, under agreement number 701811J333. The Copper River Native Association provided locally-hired technicians, John Sutton and John Hutchinson, to assisted with field operations. The U.S. fish and Wildlife Genetics laboratory conducted the genetic analysis and drafted the genetics chapter of this report. BLM provided in-kind helicopter support for the Dickey Lake and Hungry Hollow Creek phases of the project. Elijah Waters (BLM) provided sampling and logistical support throughout the study. Ken Alt, Gordon Haas and Chris Stark of Trout Unlimited volunteered to assist with field sampling. ADF&G personnel that assisted with field sampling included: Steve Stroka, Lynn-Perry-Plake, and Brendan Scanlon who helped crew-lead, and Tom Taube, Don Roach, Micheal (Wolf) Cartusciello, Richard Bettinger, Samantha Decker, Loren St Amand, Ann Crane, Josh Fisher, and Doug Edwards. Brian Taras and Dan Reed provided biometric support and assistance with field sampling. Larry Boyle provided coordination support between OSM and ADF&G. Matt Evenson reviewed the final report. Lastly a special thanks to Doug Fleming who conceived this study, drafted the investigation plan, and served as principle investigator from January 2001 to July 2002.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). *Unpublished*. Unpublished subsistence fishery harvest data for Chitina and Glennallen subdistricts. Alaska Department of Fish and Game, Glennallen, Alaska.

Albin, D. P. 1977. The fisheries and fish habitat of the Gulkana River, Alaska. Bureau of Land Management report, Anchorage District Office, Anchorage, Alaska.

Banks, M. A., M. S. Blouin, B. A. Baldwin, V. K. Rashbrook, H. A. Fitzgerald, S. M. Blankenship, and D. Hedgecock. 1999. Isolation and inheritance of novel microsatellites in chinook salmon (*Oncorhynchus tshawytscha*). J. Hered. 90:281-288.

Beere, M. C. 1996. Movements of summer run steelhead trout tagged with radio transmitters in the Babine River during Spring, 1995. Unpublished manuscript Skeena Fisheries Report #94, 23 pp. British Columbia Ministry of Environment, Lands, and Parks. Smithers, B.C..

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.

Brink, S. R. 1995. Summer habitat ecology of rainbow trout in the Middle Fork of the Gulkana River, Alaska. MS Thesis, University of Alaska, Fairbanks. 158 pp.

Burger, C. M., M. Scott, M. Small, and W. Potterville. 1983. Overwintering and spawning areas of steelhead trout in tributaries of the Upper Copper River, Alaska. USFWS, Final Report, National Fisheries Research Center. 24 pp.

Conover, W. J. 1980. Practical nonparametric statistics, second edition. John Wiley and Sons, New York.

Daniel, W. W. 1978. Applied nonparametric statistics. Houghton Mifflin Co., Boston, Massachusetts.

Fleming, D. F. 1999. Surveys and stock monitoring of rainbow and steelhead trout in the upper Copper River drainage during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-37, Anchorage.

Fleming, D. F. 2000. Stock assessment of rainbow trout in Summit Lake and surveys of rainbow and steelhead trout in the Gulkana River drainage, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-33, Anchorage

Fleming, D. F. 2004. Seasonal habitat use and experimental video enumeration of rainbow trout within the Gulkana River drainage, 1999-2000. Alaska Department of Fish and Game, Fishery Data Series No. 04-04, Anchorage.

REFERENCES CITED (Continued)

Flebbe, P. A. 1994. A regional view of the Margins: Salmonid abundance and distribution in the Southern Appalachian Mountains of North Carolina and Virginia. Transactions of the American Fisheries Society 123:657-667.

Goudet, J. 2001. FSTAT, a program to estimate and test gene diversities and fixation indices, version 2.9.3. Available from http://www.unil.ch/izea/softwares/fstat.html.

Heath, D. D., S. Pollard, and C. Herbinger. 2001. Genetic structure and relationships among steelhead trout (*Oncorhynchus mykiss*) populations in British Columbia. Heredity 86:618-627.

Hooten, R. S. 1987. Catch and release as a management strategy for steelhead in British Columbia. In R. Barnhart and T. Roelofs, editors, proceedings of: Catch and Release Fishing – A Decade of Experience. Humboldt State University, Arcata, California.

Jonsson, B., N. Jonsson. 1993. Partial migration: niche shift versus sexual maturation in fishes. Reviews in Fish Biology and Fisheries 3:348-365.

Lough, M. J. 1983. Radio telemetry studies of summer run steelhead trout in the Skeena River drainage, 1979, with particular reference to Morice, Suskwa, Kispiox, Kitwanga and Zymoetz rivers and Toboggan Creek, 1980. Unpublished manuscript Skeena Fisheries Report #80-04 (S.E.P.), 73 pp. British Columbia Ministry of Environment, Lands, and Parks. Smithers, B.C.

O'Connell, M., R. G. Danzmann, J.-M. Cornuet, J. M. Wright, and M. M. Ferguson. 1997. Differentiation of rainbow trout (*Oncorhynchus mykiss*) populations in Lake Ontario and the evaluation of the stepwise mutation and infinite allele mutation models using microsatellite variability. Can. J. Fish. Aquat. Sci. 54:1391-1399.

Olsen, J. B., P. Bentzen, and J. E. Seeb. 1998. Characterization of seven microsatellite loci derived from pink salmon. Mol. Ecol. 7:1087-1089.

Olsen, J. B., S. L. Wilson, E. J. Kretschmer, K. C. Jones, and J. E. Seeb. 2000. Characterization of 14 tetranucleotide microsatellite loci derived from sockeye salmon. Mol. Ecol. 9:2155-2234.

Palti, Y. M., R. Fincham, and C. E. Rexroad III. 2002. Characterization of 38 polymorphic microsatellite markers for rainbow trout (Oncorhynchus mykiss). Mol. Ecol. Notes 2:449-452.

Schwanke, Craig, J. 2002. Abundance and movement of the rainbow trout spawning stock in the upper Naknek River, Alaska. Masters Thesis. University of Wyoming.

Scribner, K. T., J. R. Gust, and R. L. Fields. 1996. Isolation and characterization of novel salmon microsatellite loci: cross-species amplification and population genetic applications. Can. J. Fish. Aquat. Sci. 53:833-841.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Stark, T. C. 1999. Spawning stocks and juvenile summer habitat of rainbow trout and steelhead, Gulkana River, Alaska. MS Thesis, University of Alaska, Fairbanks.

Weir, B. S., C. C. Cockerham. 1984. Estimating F-statistics for the analysis of population structure. Evolution 38:1358-1370.

Williams, F. T. 1964. Inventory and cataloging of sport fish and sport fish waters of the Copper River and Prince Williams Sound drainage, and Upper Susitna River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1963-1964, Project F-5-R-5, (11-A), Juneau.

Williams, F. T., and W. D. Potterville. 1985. Glennallen/Prince Williams Sound angler use and stock assessment studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26 (G-I-F), Juneau.

APPENDIX A

Appendix A.–Methodologies for alleviating bias due to gear selectivity.

	Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]		
	Fail to reject H_o	Fail to reject H_o
	Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]		
	Fail to reject H_o	Reject H_o
	Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event.	
Case III[e]		
	Reject H_o	Fail to reject H_o
	Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]		
	Reject H_o	Reject H_o
	Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Estimate length and age distributions from second event and adjust these estimates for differential capture probabilities.

APPENDIX B

Appendix B1.–Methodologies for Underwater Videography and identification of steelhead and rainbow trout.

Images of fish passing through the chute were recorded by a Sony™ SSCDC54A high-resolution (0.in format CCD) color closed-circuit television video camera submerged in a custom manufactured waterproof housing. The closed-circuit television (CCTV) camera had low light sensitivity (0.5 lux) and was sensitive to visible spectrum lighting, allowing nighttime recording under illumination generated by an Ikelite™ underwater video light. Images were transferred via RG-59 coaxial cable to a Kaletel™ DVMRe-4CD digital video recorder where they were recorded from 10- 30 frames-per-second and stored on a 75 gigabyte hard drive. All equipment was powered by 12 VDC power supplied by four deep-cycle golf-cart batteries charged from solar panels and a Honda™ EU 2000 generator.

Because physical differences between rainbow trout and steelhead can be subtle, sufficient image quality was needed to assure accurate classification. Physical features used in interpreting video images for classification included:

1. the coloration pattern: steelhead have a broad reddish band extending downward toward the ventral surfaces, whereas resident rainbow trout have a more centralized and narrow red stripe or band;
2. the spotting density: the density on steelhead is notably lower than on resident rainbow trout;
3. the girth-to-length ratio: the ratio for steelhead is smaller when compared to rainbow trout that appear more robust and stout; and,
4. the presence of a scar from sea lice above the anal fin: not all steelhead have a pronounced scar, but it is unique to steelhead.

Video editing was conducted later using a 10-in color Tatung™ security monitor and the digital video recorder. Images were subjectively examined relative to visual cues used to classify rainbow trout and steelhead to determine whether image quality was sufficient.

APPENDIX C

Appendix C1.–Length statistics for all steelhead and rainbow trout sampled at the Dickey Lake study area, 2001 – 2002.

			Sample Size	Length (mm FL)		
Year	Species	Sex	n	Average	Range	SD
2001	Steelhead					
		Male	23	731	510 - 820	71
		Female	45	718	525 - 840	56
		All	68	722	510 - 840	61
2001	Rainbow					
		Male	71	438	240 - 590	69
		Female	19	511	415 - 665	68
		All	90	453	240 - 665	75
2002	Steelhead					
		Male	27	717	460 - 840	93
		Female	60	704	505 - 810	52
		All	87	708	460 - 840	67
2002	Rainbow					
		Male	134	440	260 - 630	68
		Female	56	473	330 - 615	61
		All	190	449	260 - 630	68

Appendix C2.–Average length and weight of steelhead sampled by sex at the Lower Hanagita Lake study area, 2001 and 2002.

	Length (mm FL)				Weight (kg)			
	n	Average	Range	SD	N	Average	Range	SD
2001								
Male	113	676	495 - 890	102	94	3.2	1.10 - 6.14	1.2
Female	159	663	470 - 825	68	150	3.0	0.04 - 5.24	0.8
All fish	274	667	310 - 890	890	248	3.1	1.10 - 6.14	1.0
2002								
Male	57	691	200 - 880	86	A			
Female	83	664	530 - 805	44				
All fish	140	675	200 - 880	65				

[a] Steelhead were not weighed in 2002.

Appendix C3.–Average lengths of steelhead and rainbow trout by sex sampled at the Hungry Hollow weir trap, 2003**.**

		Sample Size	Length (mm FL)		
Species	Sex	n	Average	Range	SD
Steelhead					
	Male	18	678	400 - 810	103
	Female	45	688	490 - 810	60
	All	63	685	400 - 810	74
Rainbow					
	Male	55	440	320 - 705	65
	Female	26	470	350 - 655	74
	All	81	450	320 - 705	69

APPENDIX D

Appendix D1.–Number of marked and unmarked steelhead examined during the second event by sex at the Dickey Lake study area, 2001. Test: All steelhead had equal probabilities of capture in the first event regardless of sex.

Category	Sex		Total
	Male	Female	
Marked (m_2)	3	6	9
Unmarked (n_2-m_2)	14	19	33
Examined (n_2)	17	25	42[a]
$P_{capture}$ 1st Event (m_2/n_2)	0.18	0.24	0.21
χ^2 = 0.24, df = 1, P-value = 0.62			

[a] One fish during the second event was not sexed.

Appendix D2.–Number of recaptured and not recaptured steelhead examined during the second event by sex at the Dickey Lake study area, 2001. Test: All steelhead had equal probabilities of capture in the second event regardless of sex.

Category	Sex		Total
	Male	Female	
Recaptured (m2)	3	6	9
Not Recaptured (n1-m2)	5	13	18
Marked (n1)	8	19	27 [a]
$P_{capture}$ 2nd Event (m2/n1)	0.38	0.31	0.33
χ^2 = 0.09, df = 1, P-value = 0.77			

[a] One fish during the first event was not sexed.

Appendix D3.–Number of recaptured and not recaptured steelhead examined during the second event by sampling sections at the Dickey Lake study area, 2001. Test: probability of capture during the second event was independent of where during the first event it was marked.

Category	Sampling Sections			
	Upper	Middle	Lower	Total
Recaptured (m_2)	4	0	5	9
Not Recaptured (n_1-m_2)	5	3	11	19
Marked (n_1)	9	3	16	28
$P_{capture}$ 2nd Event (m_2/n_1)	0.44	0	0.31	0.32
χ^2 = 2.05, df = 2, P-value = 0.36				

Appendix D4.–Number of recaptured and not recaptured steelhead examined during the second event by first event sampling period at the Dickey Lake study area, 2001. Test: probability of capture during the second event was independent of when during the first event it was marked.

	First event sampling period			
Category	May 28 to 31	June 1 to 4	June 7 to 9	Total
Recaptured (m_2)	3	5	1	9
Not Recaptured (n_1-m_2)	2	15	2	19
Marked (n_1)	5	20	3	28
$P_{capture}$ 2nd Event (m_2/n_1)	0.60	0.25	0.33	0.32
	χ^2 = 2.25, df = 2, P-value = 0.32			

Appendix D5.–Number of marked and unmarked steelhead examined during the second event by second event sampling period at the Dickey Lake study area, 2001. Test: probability of capture during the first event was independent of when during the second event it was captured.

	Second event sampling period		
Category	June 6 to 16	June 17 to 18	Total
Marked (m2)	3	6	9
Unmarked (n2-m2)	24	10	34
Examined (n2)	27	16	43
$P_{capture}$ 1st Event (m2/n2)	0.11	0.38	0.21
	χ^2 = 4.23, df = 1, P-value = 0.04		

Appendix D6.–Number of marked and unmarked steelhead examined during the second event by second event capture gear at the Dickey Lake study area, 2001. Test: probability of capture was similar during the second event between fish caught during the second event using hook-and-line gear or downstream fish trap**.**

	Capture gear		
Category	Hook-and-line	Weir trap	Total
Marked (m2)	4	5	9
Unmarked (n2-m2)	20	14	34
Examined (n2)	24	19	43
$P_{capture}$ 1st Event (m2/n2)	0.17	0.26	0.21
	χ^2 = 0.60, df = 1, P-value = 0.43		

Appendix D7.–Number of marked and unmarked steelhead examined during the second event by sex at the Dickey Lake study area, 2002. Test: All steelhead had equal probabilities of capture in the first event regardless of sex.

Category	Sex		Total
	Male	Female	
Marked (m2)	7	9	16
Unmarked (n2-m2)	9	23	32
Examined (n2)	16	32	48
$P_{capture}$ 1st Event (m2/n2)	0.43	0.28	0.33
χ^2 = 1.71, df = 1, P-value = 0.28			

Appendix D8.–Number of recaptured and not recaptured steelhead examined during the second event by sex at the Dickey Lake study area, 2002. Test: All steelhead had equal probabilities of capture in the second event regardless of sex.

Category	Sex		Total
	Male	Female	
Recaptured (m2)	5	11	16
Not Recaptured (n1-m2)	6	17	23
Marked (n1)	11	28	39
$P_{capture}$ 2nd Event (m2/n1)	0.45	0.39	0.41
χ^2 = 0.12, df = 1, P-value = 0.72			

Appendix D9.–Number of recaptured and not recaptured steelhead examined during the second event by sampling sections at the Dickey Lake study area, 2002. Test: probability of capture during the second event was independent of where during the first event it was marked.

Category	Sampling Sections			Total
	Upper	Middle	Lower	
Recaptured (m_2)	8	7	1	16
Not Recaptured (n_1-m_2)	7	12	4	23
Marked (n_1)	15	19	5	39
$P_{capture}$ 2^{nd} Event (m_2/n_1)	0.46	0.75	0.63	0.41
χ^2 = 1.99, df = 2, P-value = 0.37				

Appendix D10.–Number of recaptured and not recaptured steelhead examined during the second event by first event sampling period at the Dickey Lake study area, 2002. Test: probability of capture during the second event was independent of when during the first event it was marked.

Category	First event sampling period			Total
	May 28 to 31	June 1 to 4	June 7 to 9	
Recaptured (m2)	6	3	7	16
Not Recaptured (n1-m2)	5	11	7	23
Marked (n1)	11	14	14	39
$P_{capture}$ 2nd Event (m2/n1)	0.55	0.21	0.50	0.41
	$\chi^2 = 3.51$, df = 2, P-value = 0.17			

Appendix D11.–Number of marked and unmarked steelhead examined during the second event by second event sampling period at the Dickey Lake study area, 2002. Test: probability of capture during the first event was independent of when it was marked.

Category	Second Event Sampling Period			Total
	June 4 to 8	June 9 to 13	June 14 to19	
Marked (m_2)	5	7	4	16
Unmarked (n_2-m_2)	16	9	7	32
Examined (n_2)	21	16	11	48
$P_{capture}$ 1^{nd} Event (m_2/n_2)	0.24	0.44	0.37	0.33
	$\chi^2 = 1.68$, df = 2, P-value = 0.43			

Appendix D12.–Number of marked and unmarked rainbow trout examined during the second event by sex at the Dickey Lake study area, 2002. Test: All rainbow trout had equal probabilities of capture in the first event regardless of sex.

Category	Sex		Total
	Male	Female	
Marked (m_2)	19	4	23
Unmarked (n_2-m_2)	84	46	130
Examined (n_2)	103	50	153
$P_{capture}$ 1^{st} Event (m_2/n_2)	0.18	0.08	0.15
	$\chi^2 = 2.88$, df = 1, P-value = 0.09		

Appendix D13.–Number of recaptured and not recaptured rainbow trout examined during the second event by sex at the Dickey Lake study area, 2002. Test: All rainbow trout had equal probabilities of capture in the second event regardless of sex.

	Sex		
Category	Male	Female	Total
Recaptured (m_2)	19	4	23
Not Recaptured (n_1-m_2)	12	2	14
Marked (n_1)	31	6	37
$P_{capture}$ 2nd Event (m_2/n_1)	0.50	0.66	0.62

$\chi^2 = 0.06$, df = 1, P-value = 0.80

Appendix D14.–Number of recaptured and not recaptured rainbow trout examined during the second event by sampling sections at the Dickey Lake study area, 2002. Test: probability of capture during the second event was independent of where during the first event it was marked.

	Marking Section			
Category	Upper	Middle	Lower	Total
Recaptured (m_2)	6	12	5	23
Not Recaptured (n_1-m_2)	7	4	3	14
Marked (n_1)	13	16	8	37
$P_{capture}$ 2nd Event (m_2/n_1)	0.46	0.75	0.63	0.62

$\chi^2 = 2.98$, df = 2, P-value = 0.23

Appendix D15.–Number of recaptured and not recaptured rainbow trout examined during the second event by first event sampling period at the Dickey Lake study area, 2002. Test: probability of capture during the second event was independent of when during the first event it was marked.

	First Event Sampling Period			
Category	May 28 to 31	June 1 to 4	June 7 to 9	Total
Recaptured (m_2)	7	11	5	23
Not Recaptured (n_1-m_2)	5	3	6	14
Marked (n_1)	12	14	11	37
$P_{capture}$ 2nd Event (m_2/n_1)	0.58	0.79	0.45	0.62

$\chi^2 = 2.98$, df = 2, P-value = 0.23

Appendix D16.–Number of marked and unmarked rainbow trout examined during the second event by second sampling period at the Dickey Lake study area, 2002. Test: probability of capture during the first event was independent of when during the second event it was examined.

Category	Second Event Sampling Period			Total
	June 4 to 8	June 9 to 13	June 14 to19	
Marked (m_2)	7	4	12	23
Unmarked (n_2-m_2)	48	31	51	130
Examined (n_2)	55	35	63	153
$P_{capture}$ 1nd Event (m_2/n_2)	0.13	0.11	0.19	0.15
	χ^2 = 1.38, df = 2, P-value = 0.50			

Appendix D17.–Number of marked and unmarked steelhead examined during the second event by sex at the Hanagita River spawning area, 2002. Test: All steelhead had equal probabilities of capture in the first event regardless of sex.

Category	Sex		Total
	Male	Female	
Marked (m_2)	14	8	21
Unmarked (n_2-m_2)	2	2	4
Examined (n_2)	14	10	26
$P_{capture}$ 1st Event (m_2/n_2)	0.88	0.80	0.85
	χ^2 = 0.27, df = 1, P-value = 0.61		

Appendix D18.–Test: Number of recaptured and not recaptured steelhead by capture location at the lower Hanagita Lake study area, 2001-2002. The probability of capture in the second event (during spawning) was independent of where marked (either in the weir trap or in downriver reaches); or mixing occurred during the overwintering period.

Category	Capture Location		Total
	In Weir Trap	Below Weir Trap	
Recaptured (m_2)	21	1	22
Not Recaptured (n_1-m_2)	244	11	255
Marked (n_1)	265	12	277
$P_{capture}$ 2^{nd} Event (m_2/n_1)	0.08	0.09	0.08

$\chi^2 = 0.01$, df = 1, P-value = 0.92

Appendix D19.–Number of recaptured and not recaptured steelhead examined by first event capture period at the lower Hanagita Lake study area, 2001-2002. Test: The probability of capture in the second event was independent of when during the first event it was marked; or mixing of early- and late-arriving steelhead occurred during the overwintering period.

Category	Capture Period		Total
	Sept. 1 to 14	Sept 15 to 30	
Recaptured (m_2)	13	8	21[a]
Not Recaptured (n_1-m_2)	136	120	256
Marked (n_1)	149	128	277
$P_{capture}$ 2^{nd} Event (m_2/n_1)	0.09	0.06	0.08

$\chi^2 = 0.62$, df = 1, P-value = 0.43

[a] One of the 22 recaptured fish lost its numbered tag and the capture period could not be identified.