Fishery Data Series No. 00-33

Stock Assessment of Rainbow Trout in Summit Lake and Surveys of Rainbow and Steelhead Trout in the Gulkana River, 1999

by
Douglas F. Fleming

December 2000

Alaska Department of Fish and Game | Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
Foot	ft
Gallon	gal
Inch	in
Mile	mi
Ounce	oz
Pound	lb
Quart	qt
Yard	yd

Spell out acre and ton.

Time and temperature

Day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
Minute	min
Second	s

Spell out year, month, and week.

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	Cov
degree (angular or temperature)	°
degrees of freedom	Df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	Ln
logarithm (base 10)	Log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	X
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
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 00-33

STOCK ASSESSMENT OF RAINBOW TROUT IN SUMMIT LAKE AND SURVEYS OF RAINBOW AND STEELHEAD TROUT IN THE GULKANA RIVER DRAINAGE, 1999

by

Douglas F. Fleming
Division of Sport Fish, Fairbanks

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

December 2000

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-15 Job No. R-3-2(f).

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. 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.

Douglas F. Fleming
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as:
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.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

Rainbow and steelhead trout studies were conducted in 1999 in the Upper Copper Upper Susitna Management Area, which is located in south central Interior Alaska. Spring sampling was conducted on resident rainbow trout and anadromous steelhead in several spawning areas within the Middle Fork Gulkana River. However, attempts to conduct aerial survey counts of spawning rainbow and steelhead trout were unsuccessful due to poor water conditions, particularly in the west fork Gulkana drainages. Between May 28 and June 1, 20 resident rainbow and 15 steelhead trout were captured and sampled at a Middle Fork Gulkana River spawning area located between 1 and 3 mi below Dickey Lake. Within Hungry Hollow Creek, 6 resident rainbow and 4 steelhead trout were sampled on June 2 in spawning areas located 6 to 9 mi upstream of the Middle Fork Gulkana River. The sizes and ages of these spawning trout suggested that catch-and-release regulations have been helpful in maintaining a rainbow trout fishery in the Gulkana River, even though there have been increasing numbers of anglers each year.

During late June and the middle of July, the first mark-recapture stock assessment of rainbow trout was conducted at Summit Lake, near Chitina, Alaska. In the 1980s, the Summit Lake rainbow trout population was known for trophy-sized fish of 20 pounds or more. In recent times, angling reports and unreported Alaska Department of Fish and Game (ADF&G) monitoring samples have indicated a loss of the trophy-sized trout and a need for stock assessment to manage the trout in this special management area. During the first sampling event conducted during the spawning period, 1,293 trout ≥ 130 mm FL were captured and released with tags throughout the lake, and in the outlet spawning area in Bridge Creek. Following an 18-day sampling hiatus, 1,351 trout ≥ 130 mm FL were captured that included the recovery of 122 marked fish. Fish were captured with a variety of gears, but fyke traps were most effective and captured fish from 55 to 450 mm FL.

We estimated a minimum abundance of 13,767 trout ≥ 130 mm FL in the 130 ha lake at the time of the July sampling event. The experiment was limited to a minimum estimate because of difficulties associated with marking and releasing fish captured in deeper areas of the lake with gillnets. The trout ranged to a maximum observed size of 450 mm (18 in) with nearly 50% of the sample in the 130-290 mm size range, and only 10% larger than 355 mm FL (14 in +). Spawning was observed from all sizes of fish, including fish as small as 120 mm. Some of the largest sampled fish, however, were immature and found in areas away from spawning areas. The dense population of small trout in this lake appears to be stunted. This is based on the small average length at age and the observation that many small and presumably young age fish were mature.

Limnological sampling examined the primary and secondary food production and determined that although the zooplankton populations were dense, the sizes of the numerous *Daphnia longiremis* were small and may not be an important food resource for the trout. Rehabilitation of stunted salmonid populations through population thinning may improve growth and condition of Summit Lake rainbow trout.

Key Words: Rainbow trout, steelhead trout, *Oncorhynchus mykiss,* Copper River drainage, Gulkana River, Summit Lake, Bridge Creek, abundance, length composition, age composition, stunting, growth, condition factor.

INTRODUCTION

Rainbow and steelhead trout *Oncorhynchus mykiss* populations that inhabit the Upper Copper Upper Susitna Management Area (UCUSMA) are considered the northernmost wild populations of this species in North America. These trout populations are comprised of resident rainbow trout (year-round presence) and steelhead trout (anadromous) forms in varying combinations in the upper Copper River basin (Figure 1). In some lakes there are wild populations of resident rainbow trout. In other tributary drainage's where migratory access exists, the populations may include a mixture of rainbow and steelhead. Moreover, the mix of these forms may seasonally vary with the presence or absence of adult migratory steelhead. Steelhead trout in this region have been considered to have a fall-run migration from the ocean to spawning areas in freshwaters. Exploitation occurs during migrations from the ocean as incidental harvest in

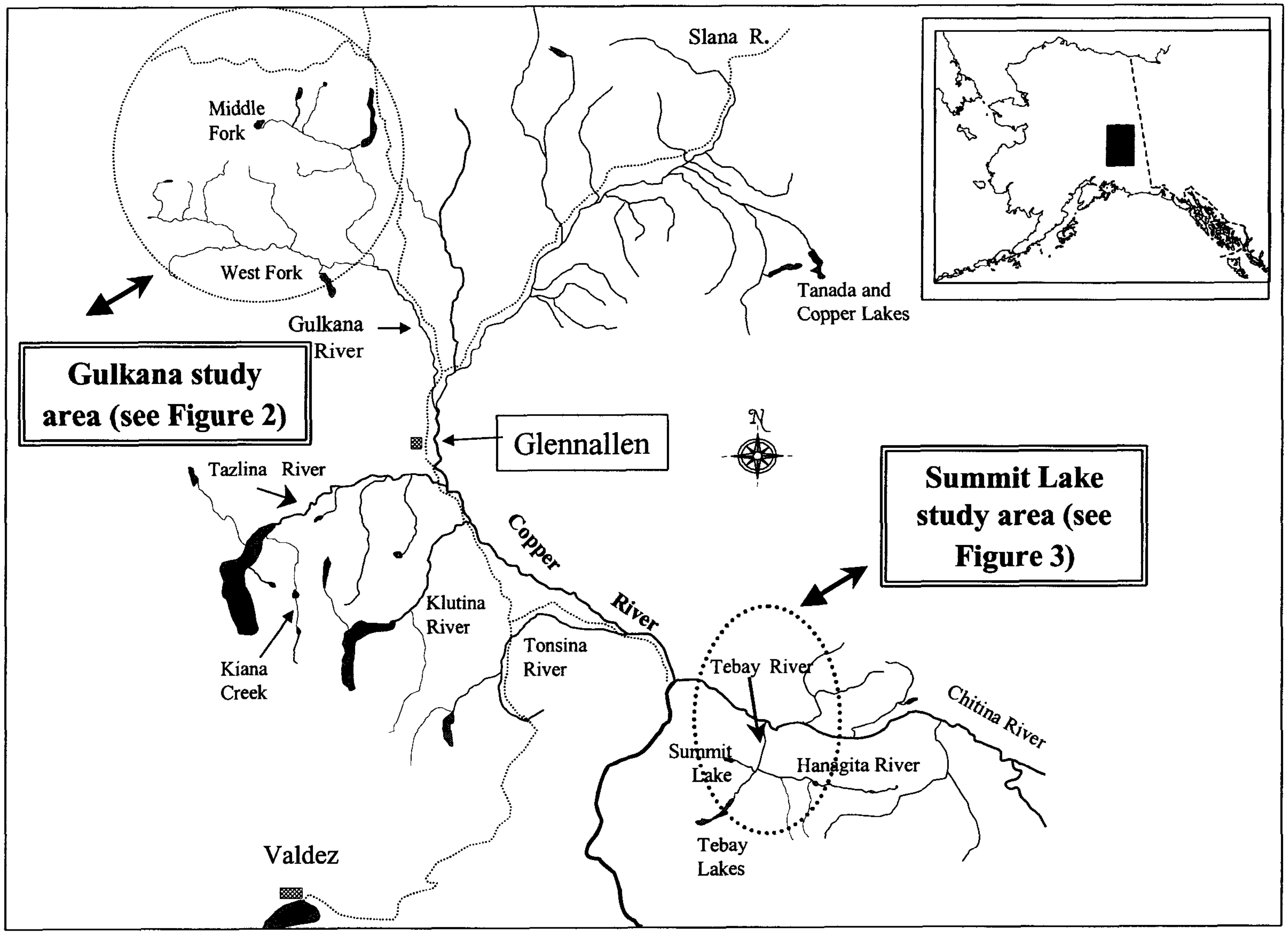

Figure 1.- The Copper River drainage, including locations (circled) of 1999 field investigations.

commercial salmon fisheries, subsistence[1] fisheries along the mainstem Copper River, and sport fisheries at or near spawning locations in Copper River tributaries. Some of the better known and easily accessed populations have been exploited by anglers for 35 or more years (ADF&G *Unpublished a*). Similar to other salmonids living on the edges of their distribution, these populations are thought to be relatively sparse and unproductive (Flebbe 1994).

Rainbow trout and steelhead inhabit the Gulkana River drainage which annually hosts thousands of recreationists in this nationally designated "Wild River" corridor (Figure 2). Rainbow trout were documented in the Tazlina River drainage at Kaina Creek during chinook salmon *O. tshawytscha* escapement surveys (C. Whitmore, Alaska Department of Fish and Game, Palmer, personal communication). Steelhead were tracked to Kaina Creek during a Copper River steelhead radio-telemetry study (Burger et al. 1983), and later spawning rainbow trout and steelhead were documented at Kaina Creek (Fleming 1999). Within the Tebay River drainage, rainbow trout are present in the Tebay Lake(s), Summit Lake, and the Tebay River, and steelhead are present in the Hanagita River and lakes. Catch and harvest data from angler surveys have indicated the presence of rainbow and steelhead trout in other Upper Copper tributaries such as the Tonsina, Klutina, and other smaller Copper Basin streams (ADF&G *Unpublished*). Anecdotal information from angler survey data, subsistence harvest reports, and other accounts indicate that additional populations of rainbow trout and steelhead may exist in the Copper River drainage.

In 1987 the Alaska Board of Fish (BOF) approved an amendment to the Cook Inlet Rainbow/Steelhead Trout Management Policy (CIRTMP), which extended the geographic coverage of the policy to include UCUSMA. This policy, renamed the Cook Inlet and Copper River Basin Rainbow/Steelhead Trout Management Policy was developed to provide a framework for rainbow and steelhead trout fishery management. This framework included that:

Policy I: native rainbow trout populations will be managed to maintain historical size and age composition and stock levels; and,

Policy II: a diversity of sport fishing opportunities for wild and hatchery rainbow/steelhead trout will be provided through establishment of special management areas by regulation.

These policies have led to more conservative regulations for all stocks of rainbow and steelhead within the UCUSMA and the creation of special management areas in the Tebay River drainage. In addition to management policies, the Alaska Board of Fisheries (BOF) gave recommendations that research:

[1]. Subsistence fisheries and harvest includes fisheries previously defined as subsistence and personal use fisheries. However, the retention of Steelhead in personal use fisheries has not been permitted since 1997.

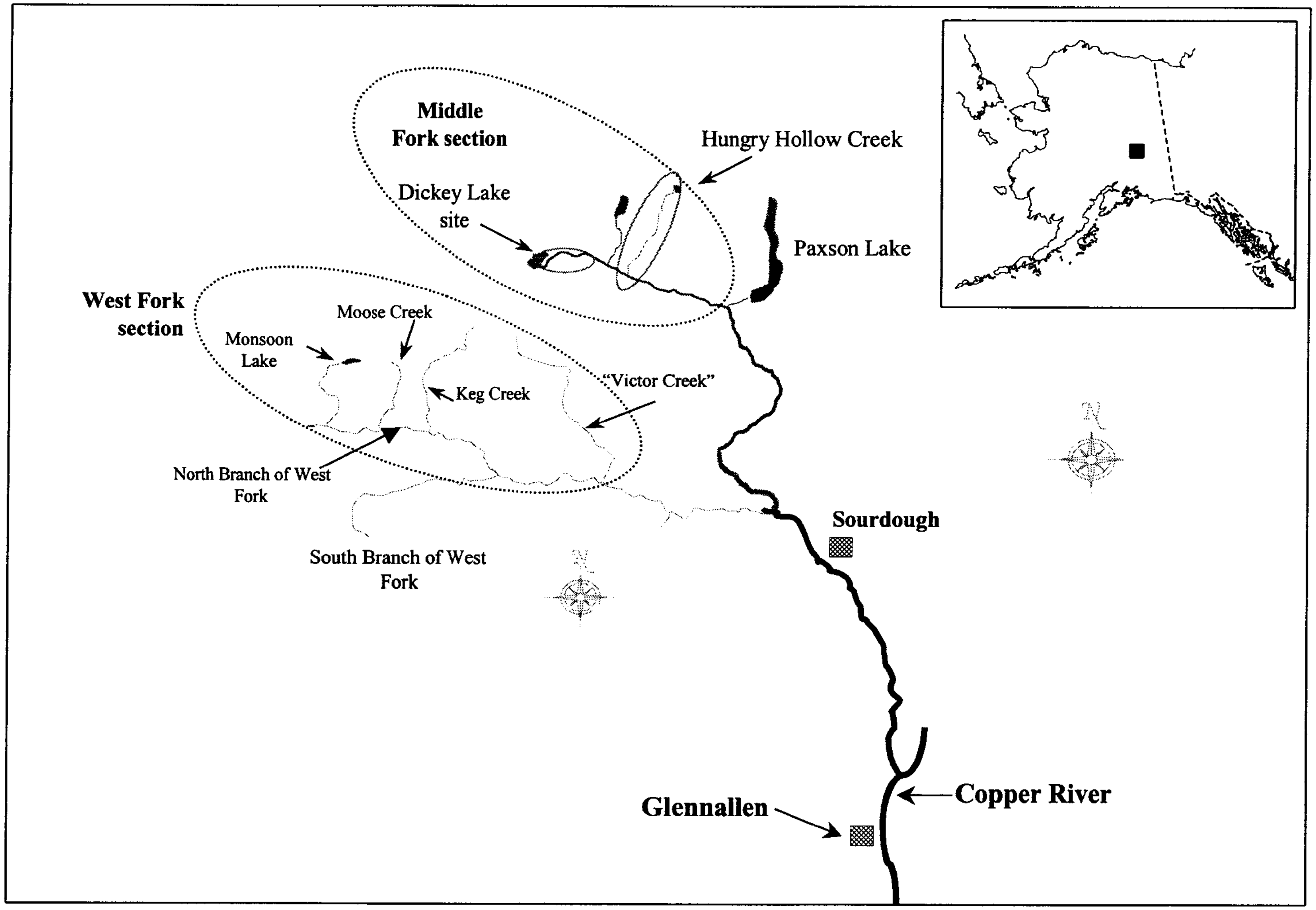

Figure 2.- The Gulkana River drainage including locations (circled) of 1999 field investigations at spawning locations along the Middle Fork Gulkana River, and areas selected within the West Fork Gulkana River drainage for aerial spawning surveys.

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

Under the guidance of this policy and from recommended research objectives, baseline biological research was initiated in 1998, which focused on rainbow and steelhead trout resources in the Upper Copper River Basin. In 1998, surveys and sampling were conducted at Kaina Creek, the Hanagita River drainage, and the Gulkana River (Fleming 1999). These studies were designed to give managers current information on these rainbow and steelhead trout stocks, to provide information to develop stock assessment methods, and to provide anglers with updated and enhanced information on trout fishing opportunities.

A small spawning aggregate of steelhead and rainbow trout was found at Kiana Creek at the outlet of Kiana Lake immediately after ice-out. This was the first documentation of actively spawning rainbow and steelhead trout in the outlet area (Fleming 1999).

Sampling and tagging efforts in the Hanagita River drainage during the middle of September 1998 did not yield estimates of abundance, but yielded information that extended the known geographic range for steelhead. This range extension upstream of Hanagita Lake led to regulatory changes by BOF in December 1999, which geographically extended the catch-and-release regulation. No resident rainbow trout were captured during the limited sampling in this drainage, but 10 steelhead were captured. There is no known record of resident rainbow inhabiting the vicinity of Hanagita Lake.

Sampling was also conducted on the Gulkana River drainage in 1998 during the spring spawning season (late May to early June) and in the summer feeding period (July). Small numbers of resident rainbow and steelhead were sampled in the known Middle Fork Gulkana spawning areas (Fleming 1999). At this time, large trout (greater than 20") were not found upstream of Sourdough along the mainstem of the Gulkana River. However, in late –July, resident rainbow were sampled along the mainstem of the Gulkana River upstream of Sourdough. The sizes of trout sampled along with angling reports suggested that the resident rainbow trout population is healthy following the change in regulation to catch and release.

Following a management review of the Upper Copper River Management Area, further studies were initiated on the Gulkana River to assess the stock of rainbow trout in Summit Lake, near Chitina, Alaska.

GULKANA RIVER FISHERY

The Gulkana River drainage is the largest recreational fishery in the UCUSMA, and accounts for as much as 50% of the annual estimated angling-use days in this area (Mills 1979-1994; Howe et al. 1995-1999). This drainage supports the largest known rainbow trout and steelhead, chinook salmon, and Arctic grayling *Thymallus arcticus* sport fisheries within the management area (Szarzi 1996). Following the 1987 management policy, rainbow and steelhead bag limits were reduced. Bag limits were reduced from 10 fish per day, 10 in possession, with only two fish over 20 in to two per day, two in possession, with only one fish over 20 in. By 1990, managers thought the rainbow and steelhead trout population had declined and the stock could not sustain continued harvests (Szarzi 1996). Beginning in 1991, the rainbow and steelhead trout fishery in the Gulkana River has been managed by catch-and-release regulation, and progressively more gear restrictions in upstream areas where resident rainbow are frequently encountered. Since this time, anglers have been restricted to the use of unbaited artificial lures from the headwaters of the Gulkana River in the Alaska Range downstream to a regulatory marker located about 7.5 mi[2] upstream of the West Fork of the Gulkana River (Figure 2). Between this location and the Richardson Highway bridge, the use of bait was permitted during most of the year[3]. In 1997, the BOF passed further restrictions that closed portions of the Middle Fork Gulkana drainage to all angling during rainbow and steelhead trout spawning and part of the egg incubation period. This closure is from April 15-June 14, and includes portions of the middle fork from Dickey Lake downstream approximately 3 mi and all of Hungry Hollow Creek.

Since 1988, estimated angling effort on flowing waters within the drainage (Table 1) has increased (Mills 1979-1994, Howe et al. 1995-1999). The annual average estimated effort from 1977 through 1990 was approximately 13,700 angler-days. From 1991 through 1998, the average estimated effort in the Gulkana River was approximately 28,700 angler-days. Angler effort did not decline with the enactment of catch and release trout regulations. Estimates of angling effort in the commonly floated portion of the mainstem between Paxson Lake and Sourdough has climbed from roughly 3,000 angler-days in the late 1980s to over 14,000 in 1998 (Mills 1979-1994, Howe et al. 1995-1999).

Survey estimates of the sport fishery indicated a near doubling of rainbow trout catches between 1995 and 1996 (Howe et al. 1996, 1997), with only a slight (~6%) increase in estimated effort between the two years (Table 1). It is likely that increased survival through catch and release regulations has allowed the population to rebuild, and offers anglers the chance to catch more, and larger trout (Fleming 1999). Gulkana River steelhead fishing mortality by user groups other

---

[2] In this report, distances and elevations describing geography, habitat, and angling regulations are in English units of measure. Estimates of fish lengths, such as in composition estimates, are in metric units.

[3]. Prior to the December 1999 meeting of the Alaska Board of Fish, bait could be used all year in all flowing waters downstream of the described regulatory marker and upstream of the Richardson Highway bridge. At the December BOF meeting, a regulation was enacted to restrict the use of bait to the period between June 1st and July 19th.

Table 1.-Yearly effort[a], harvest[b], and catch of wild rainbow trout and steelhead by sport anglers fishing the Gulkana River from 1977-1996.

		Rainbow trout		Steelhead trout	
Year	Effort	Harvest	Catch	Harvest	Catch
1977	4,165	752	---	0	---
1978	6,570	1,256	---	0	---
1979	17,323	1,455	---	0	---
1980	13,752	1,249	---	0	---
1981	14,430	1,469	---	0	---
1982	14,979	1,257	---	52	---
1983	16,911	1,341	---	21	---
1984	12,870	1,266	---	0	---
1985	14,080	2,098	---	137	---
1986	14,219	1,104	---	18	---
1987	17,354	1,517	---	104	---
1988	11,299	1,218	---	18	---
1989	15,285	656	---	47	---
1990	18,782	425	2,395	34	68
1991	20,944	150	1,133	0	26
1992	25,650	16	1,654	8	39
1993	27,034	40	2,724	0	102
1994	25,357	0	3,380	0	0
1995	32,656	0	3,958	0	0
1996	34,738	0	6,694	0	121
1997	31,831	0	8,114	0	126
1998	32,083	0	5,428	0	109

[a] Estimates of angling effort included the Gulkana River only, and do not include effort within lakes. Effort is angler days.

[b] Estimates of harvest included fish harvested at Paxson Lake; rainbow trout fishing and harvests occur in the outlet area.

than sport fisheries is unknown. The largest estimated sport catch of steelhead (252), however, was reported in 1998 (Howe et al. 1999).

To date, there have been no stock assessments on the Gulkana designed to estimate stock size or composition of rainbow trout/steelhead. In 1998, sampling conducted at spawning areas of the Middle Fork Gulkana was late relative to the peak of spawning activity. Prior to 1998, visual counts of spawners in 1993, 1994, and 1995 on the Middle Fork Gulkana ranged between 100 and 150 rainbow trout and 20 and 30 steelhead. These were differentiated based on relative sizes (Stark 1999). In 1984, the Alaska Department of Fish and Game (ADF&G) and the U.S. Bureau of Land Management staff conducted helicopter and stream surveys that resulted in count estimates of approximately 200 steelhead using known spawning areas within the Middle Fork Gulkana drainage (Williams and Potterville (1985). These were gross counts of larger rainbow trout and steelhead combined.

Following the initial attempts in 1998 to sample and characterize resident rainbow and steelhead in spawning areas in the Gulkana River, managers identified a need to continue sampling those locations and to locate any other spawning concentrations.

THE SUMMIT LAKE FISHERY

Within the Tebay River drainage, rainbow trout inhabit the headwater lakes, namely the Tebay and Summit lakes (Figure 1) and small numbers of migrating steelhead pass upstream to the Hanagita lakes to spawn. Following adoption of the Rainbow/Steelhead Trout Management Policy, the fisheries in this relatively small drainage were divided into special management areas (i.e., harvest, catch-and-release, and trophy waters) by regulation. Anglers at upper, middle, and lower Tebay lakes can catch and harvest rainbow trout. Anglers can catch-and-release steelhead trout in the Hanagita River drainage[4]. Anglers can fish for large rainbow trout and harvest smaller trout at Summit Lake and Bridge Creek, which has been designated a trophy fishery[5].

During the 1980s, Summit Lake was known for its trophy-size rainbow trout. There is no information about rainbow trout in this lake prior to the first ADF&G account in 1983. Up to that time it was thought to be a barren alpine lake. Later it was learned that Summit Lake was unofficially stocked with rainbow trout in or about 1962 by individuals who transported angled trout from Tebay Lake (ADF&G *Unpublished*). ADF&G and National Park Service (NPS) staff from the Wrangell-St. Elias National Park have conducted periodic visits to the lake since 1983, and no other fish species have been found. Initial gillnet sampling conducted in 1983 and 1984 within the lake body indicated large rainbow trout were present in the lake, but few smaller and younger trout were sampled (Williams and Potterville 1984, 1985). Around 1985, fishing activity increased. Anglers targeted rainbow trout that were greater than 30" and over 20 lbs. Soon after this, a regulatory action was initiated through Emergency Orders and BOF actions:

---

[4]. In the 1999 Alaska Board of Fish meeting, catch and release regulations for rainbow trout and steelhead in the Hanagita River drainage were extended to all waters of the Hanagita River drainage, and the portion of the Tebay River downstream from its confluence with the Hanagita River.

[5]. Summit Lake regulation changes occurred following the December 1999 Alaska Board of Fish Meeting, that reflected management decisions based on the outcome of this current study. Beginning in 2000, anglers will be able to retain 10 trout per day/possession under 12" total length.

1987 Summit Lake/Bridge Creek closed to fishing during spawning period by Emergency Order.

1988 Summit Lake/Bridge Creek spawning closure September 21 to July 10.

1989 Summit Lake/Bridge Creek and lower Hanagita drainage restricted to unbaited single hook artificial lures.

1991 Summit Lake/Bridge Creek bag and possession limit restricted to 1 fish over 32in (>810 mm FL).

Few records are known that describe angling use, catches, and harvests of trout over the brief history of this fishery. Owing to a lack of angler responses to annual statewide harvest, catch, and participation surveys (Mills 1977-1994; Howe et al. 1995-1998) estimates for the Summit Lake trout fishery were not generated.

Other surveys and sampling activities have included test-net fishing with experimental gillnets (Williams and Potterville 1984) and traps, the collection of age and length data using hook and line sampling, visual counts of spawners in the outlet area, and habitat description of the lake and its tributaries (ADF&G *Unpublished*). Age and size data, visual-spawner counts, and field notes compose the records of the Summit Lake fishery. Collectively the field notes and anecdotal accounts from anglers and commercial operators suggest that the large rainbow trout of the 1980s were overexploited or lost naturally from the population and replaced by more numerous smaller trout. About 1990, ADF&G field notes indicated an increasing number of small trout, fish in poor condition ("skinnier"), and excessive bleeding by lure-caught fish. This led to the regulation that only 1 fish over 32 in can be kept. The concern over the lost opportunity to catch larger trout and the increased number of small trout led to a proposal in 1996 to allow the harvest of smaller fish. This proposal was unsuccessful at that time. Managers identified a need to better understand the population of trout and a stock assessment was initiated in 1999.

OBJECTIVES

The research objectives for 1999 were to:

1. estimate the age and length composition of rainbow trout vulnerable to angling from spawning concentrations within the middle fork of the Gulkana River in late May and early June;
2. estimate the age and length composition of steelhead trout vulnerable to angling from spawning concentrations within the Middle Fork of the Gulkana River in late May and early June;
3. locate rainbow trout and steelhead spawning areas using aerial surveys within the headwater tributaries of the west fork of the Gulkana River and validate species present through angling and/or net capture;
4. estimate the abundance of rainbow trout within Summit Lake and Bridge Creek in the middle of July;
5. estimate the age and length composition of rainbow trout within Summit Lake and Bridge Creek in the middle of July; and,

6. estimate the proportion of trophy-sized (≥ 810 mm FL) rainbow trout in Summit Lake in the middle of July, that compose the exploitable population.

In addition to these objectives, research tasks were to:

1. conduct aerial helicopter counts of spawning trout in two known rainbow and steelhead trout spawning areas in the Middle Fork Gulkana drainage; and,
2. estimate the condition factor for rainbow trout at Summit Lake during the middle of July, using length and weight data collected during the mark-recapture stock assessment.

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. The Gulkana begins above timberline in Gunn Creek, a tributary to Summit Lake, near Paxson. However, waters of the Gulkana River may have begun within the Gulkana Glacier[6] and flowed into Summit Lake bearing glacial silts (Allin 1957). Below Summit Lake, the Gulkana River flowed into Gulkana Lake (present day Paxson Lake) also carrying glacial silt. Allin (1957) reported that below Paxson Lake's outlet, the Gulkana River retained a milky glacial color. Presently, glacial outwash from the Gulkana Glacier does not enter the Gulkana drainage.

The mainstem of the Gulkana River is joined by two major tributaries, the west fork (approximately 185 mi in length, including major tributaries) and the middle fork (25 mi in length). Access to both requires an airplane, or combinations of canoeing and overland portaging. Much of the land bordering the river is Bureau of Land Management (BLM) lands, and much of the river drainage was designated as a National Wild River in the 1980 Alaska National Interest Lands Conservation Act (ANILCA). The Ahtna Native Corporation owns most of the land downstream of Sourdough. Stream habitat within the Gulkana River drainage ranges from slow meandering reaches with sand and silt substrates to high gradient sections of class III+ rapids in several small incised canyons.

Within the Middle Fork Gulkana River (hereafter referred to as the Middle Fork), rainbow and steelhead trout use a 3 mi section for spawning and juvenile rearing. This section is downstream of Dickey Lake. Spawning and rearing also occur in 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 quantified by Stark (1999).

---

[6] I was not able to find any evidence that outflow from the Gulkana glacier was diverted by human intervention or natural occurrences. Ideas and recollection by several longtime residents about glacial silt entering Paxson Lake and the Gulkana River were not consistent with Allin (1957).

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. In the areas used by spawning rainbow and steelhead which are downstream of Wait-A-Bit Lake, the habitat is primarily composed of large cobble and pool riffle habitat with a moderately high stream gradient. Adjacent to the creek, thick riparian stands of willow *Salix* spp. are the dominant vegetation type mixed with scattered spruce *Picea* spp.

Middle Fork spawning areas (Hungry Hollow Creek and the Middle Fork downstream of Dickey Lake) were documented as steelhead spawning areas in a 1983 radiotelemetry project (Burger et al. 1983). Aerial helicopter counts of as many as 200 steelhead were made during the second year of the steelhead radiotelemetry project (Williams and Potterville 1985). These spawning areas for steelhead and resident rainbow were later sampled and described by graduate students from the University of Alaska Fairbanks. These students also conducted studies on juvenile habitat, habitat ecology, and spawning stocks of Gulkana River rainbow trout and steelhead (Brink 1995; Stark 1999).

The West Fork of the Gulkana River (hereafter referred to as the West Fork) includes two tributary drainages, the south and north branch which join at a location 51 mi up the west fork (Figure 2). The south branch flows west, then east approximately 52 mi through a series of interconnecting lakes before reaching the confluence with the north branch of the West Fork. The south branch has a very low gradient (average 6 feet per mile; range 0-24) with slow flows of tannic stained water draining a large area of wet muskeg tundra south of the Alphabet Hills. There is no documented anadromous habitat or use in the south branch (ADF&G 1998). The north branch of the West Fork is formed from a collection of runoff and lake-fed tributaries from the Alphabet Hills, which drain to the south and east. This branch includes over 90 mi of stream that is divided between the north branch (originating at Monsoon Lake), Moose and Keg creeks, and outlet streams from several unnamed lakes. The north branch drainage is characterized by clear water and steeper gradients (average 24 feet per mile; range 4-106) and provides chinook and sockeye salmon spawning and rearing habitat. Known anadromous waters make up 68% of this branch (61 mi of the 90 mi total). Below the confluence of the south and north branches, the West Fork has two tributary drainages that are documented as anadromous. The extensive Fish Lakes drainage has been the site of a sockeye salmon enhancement project conducted by the Prince William Sound Aquaculture Corporation (PWSAC). Another creek, locally identified as Victor Creek, drains the eastern portion of the Alphabet Hills and flows approximately 25 mi before joining the west fork. This creek is a documented sockeye salmon spawning stream in the lower 18 mi (ADF&G 1998).

Summit Lake

Summit Lake and Bridge Creek compose a clear water drainage that is a tributary of the Tebay River (Figures 1 and 3). The lake is approximately 2.5-mi long and 0.5-mi wide, has a surface area of 320 acres (130 ha), and depths to 74 feet (Williams and Potterville 1984). The lake is situated in an elevated valley at 2,818 feet ASL between the Chitina and Copper rivers, approximately 15 mi southeast of Chitina. The lake's exceptionally clear waters are fed by snowmelt and runoff from abutting steep slopes of the Chugach Mountains and several small inlet streams. A small inlet stream from a small unnamed pot-hole lake flows approximately 0.5 mi through several beaver dams and enters Summit Lake from the west. Along the south

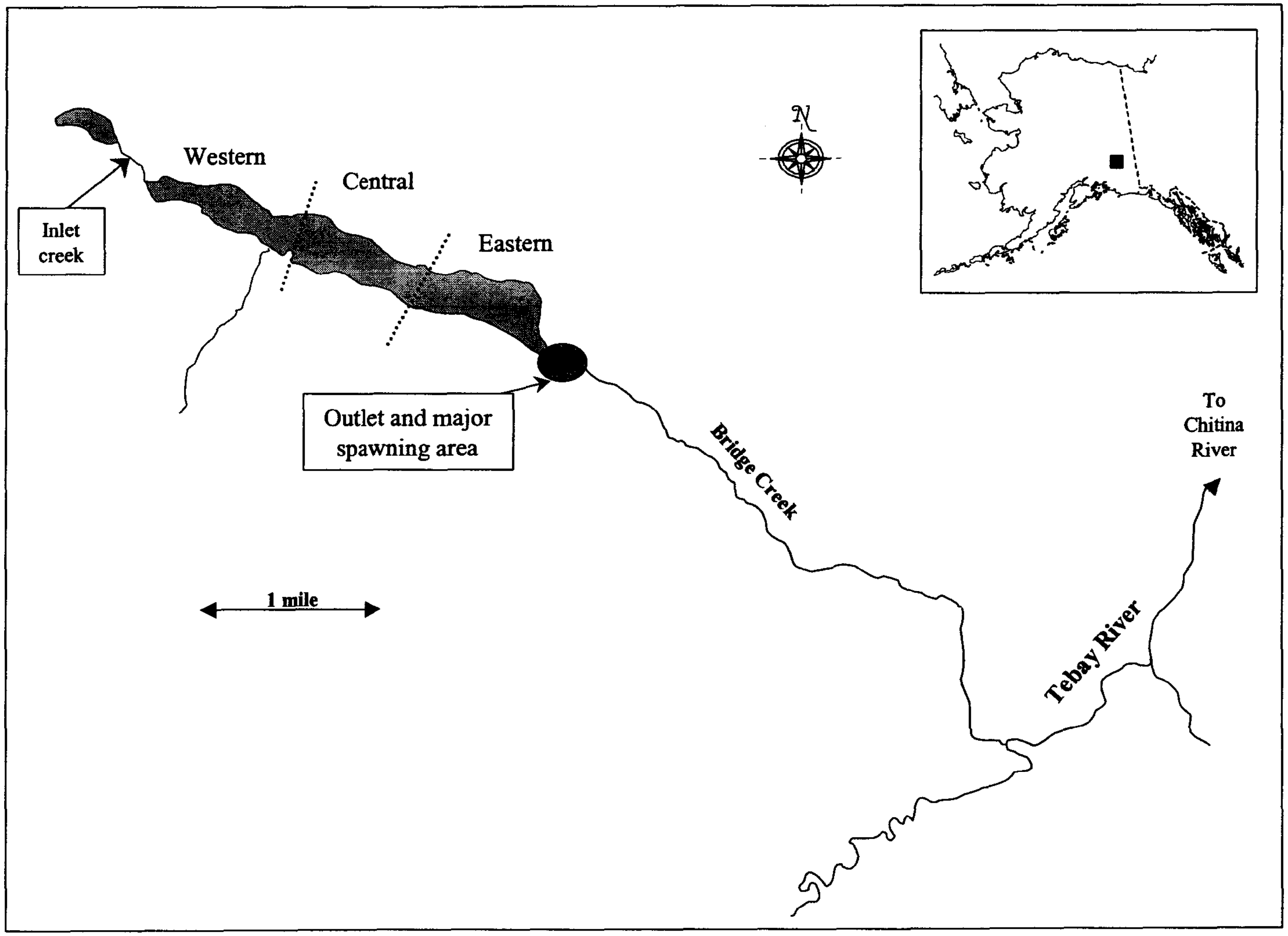

Figure 3.- Map of the Summit Lake study site showing demarcations between eastern, central, and western sampling areas.

shoreline of the lake, a second smaller tributary stream enters the lake. Carrying snowmelt from a small firn glacier valley that is high above the lake.

The lake has limited shoal areas (10% or less of its area; Williams and Potterville 1984), steeply sloping drop-offs (~1:1 gradient), and lake secchi disc depths averaging 46 ft (D. Rutz, Alaska Department of Fish and Game, Palmer, personal communication). Aquatic vegetation is scarce but includes some sedges and grasses as well as algae and phytoplankton. Water temperatures taken during August 1983 ranged from 4 °C in the inlet streams, to 11 °C in the lake and outlet (Williams and Potterville 1984). The only known fish species present in this system is rainbow trout. Information on previously available prey indicate the use of invertebrates that includes freshwater snails, leeches, amphipods, invertebrate zooplankton, and possibly fairy shrimp *Eubranchiopoda*, (Williams and Potterville 1985; M. Williams, Alaskan Wilderness Outfitters, personal communication; ADF&G *Unpublished*).

The outlet is located at the eastern end of the lake, and forms Bridge Creek. Discharge observations have ranged between 60 and 80 cubic feet per sec (CFS) near the lake outlet (D. Rutz, Alaska Department of Fish and Game, Palmer, personal communication). Spawning habitat is provided in upper Bridge Creek over clean gravel and sand bottom substrates. In the upper 500 ft the stream ranges between 10 and 20 ft wide, 1 to 2 ft deep, and with stream velocities of less than 1 $m\text{-}sec^{-1}$. Below this, the stream channel narrows with increased gradient and stream velocities, and bottom substrates include greater quantities of large cobble and small boulder. The creek's flow and gradient increases significantly over the next 4 miles as it abruptly drops 1,200 feet in elevation before entering the Tebay River. Several significant waterfalls in this section of Bridge Creek block entry of fish from the Tebay drainage. From the Bridge Creek and Tebay River confluence, the Tebay River flows 11 mi through a steep canyon and with stream gradients estimated in excess of 150 feet per mile before reaching the Chitina River.

Summit Lake and its adjoining inlet and outlet streams composed the study area in 1999. The lands adjacent to the Summit Lake and Bridge Creek drainage are in the designated wilderness area of Wrangell-St. Elias National Park. All of the study area is at or above treeline, with thick stands of low lying Willow *Salix* spp. and pockets of Alder *Alnus* spp. composing the riparian vegetation and tundra abutting the mountain slopes.

Surveys, Timing, and Field Sampling

Field investigations of rainbow and steelhead trout in the Upper Copper River basin occurred during two biologically distinct time periods: spring spawning and summer feeding. The spring spawning period has been reported to occur within a three-week period beginning in late May for many of the Copper River tributaries (Burger et al. 1983; Brink 1995; Stark 1999; Fleming 1999). Unlike the Gulkana River, the spring spawning period for trout in Summit Lake and Bridge Creek occurs between the middle of June and early July because of later break-up of the lake ice (Williams and Potterville 1985; D. Rutz, Alaska Department of Fish and Game, Palmer, personal communication).

Gulkana River

On May 27, 1999, a crew of four left the Denali Highway and traveled 19 mi by 6-wheel off road vehicles (ORV) along the Swede Lake and Middle Fork trails to reach the spawning area below

Dickey Lake. On that date, the lake was still ice covered. The crew hiked along the river and captured fish by angling. Weighted flies patterned after salmon or steelhead eggs were used to capture fish. Hooked fish were quickly brought into a large landing net downstream from other fish to avoid spooking uncaught fish that remained in the spawning aggregates. Fish were sampled immediately following capture to minimize stress from handling. Each trout was contained in a submerged deep-bag landing net during sampling to avoid exposure to air (Ferguson and Tufts 1992).

Sampled pre-spawning trout were classified as rainbow trout or steelhead based on visual characteristics. Rainbow trout had a dense spotting pattern over all of the fish, a medial rose- to red-colored stripe, and scale patterns that showed no signs of the extensive saltwater growth as seen in steelhead. Steelhead had fewer spots that were not rounded and copper to reddish-brown coloration below the lateral line that extended to the ventral surfaces. Additionally, all sampled fish of this description had an abraded patch of scales and integument along the margin of the anal fin where sea lice *Lepeophtheirus salmonis* had been attached, and extensive saltwater growth was later observed in the scale pattern.

Fish were measured to the nearest 1 mm FL, given a partial finclip, and tagged with an individually numbered Hallprint™ anchor tag (44,000 series) prior to release. A portion of the upper caudal fin was removed and the fin tissue (~0.4 in^2 or 1 cm^2) was preserved in alcohol and stored in individual vials for future genetic analysis. A smear of at least five scales was collected from each rainbow or steelhead trout. Scales were removed by tweezers from an area approximately two-scale rows above the lateral line, along a diagonal running from the posterior insertion of the dorsal fin towards the anterior insertion of the anal fin (Alvord 1954; Maher and Larkin 1955). The adipose fin of fish sampled near Dickey Lake was partially clipped in a horizontal direction similar to the method of Stark (1999). Additionally, all captured fish were examined for markings from earlier sampling to define patterns of movement and stock mixing from fish marked during the spring and summer of 1998.

On May 29, a chartered Robson R-22 helicopter was flown to the field camp at Dickey Lake for use in aerial surveys of the Middle and West forks. On May 29, aerial counts of spawning trout (rainbow and steelhead) were conducted below Dickey Lake and at Hungry Hollow. On the next day, surveys of the West Fork were conducted but could not be completed because of high runoff levels in 3 of the 4 designated stream segments. In addition to aerial surveys, we conducted visual counts of rainbow trout and steelhead throughout the spawning area from the stream bank or adjacent edges of 6 to 9 foot high deposits of overflow ice (Aufeis) on June 1, prior to breaking camp and going to Hungry Hollow.

On June 1, 1999, a crew of three left Dickey Lake and traveled 15 mi to Hungry Hollow Creek, which is the other known spawning area in the Gulkana. This crew hiked 4 mi upstream along Hungry Hollow Creek to Wait-a-Bit Lake (Figure 2). The crew then used angling to capture rainbow and steelhead trout from spawning concentrations along the creek. Sampling procedures were similar to the Dickey Lake spawning area except that fish were given a partial adipose finclip, in which the trailing lobe was clipped vertically instead of horizontally.

Summit Lake

To address the study objectives and to collect relevant data that would be comparable to past investigations at Summit Lake, sample timing included the late June spawning period and the summer feeding period. Abundance of rainbow trout was estimated by the Petersen single-marking event mark-recapture method (Seber 1982). Two eight-day sampling trips were conducted at the Summit Lake and Bridge Creek study area for stock assessment. On June 24, a crew of 4 traveled by floatplane (DHC-2 Beaver) set up a field camp at Summit Lake, and began the first of two sampling events for the mark-recapture experiment. The first sampling event was completed on June 30. After a 15-day hiatus, the second sampling event began on July 16. The second sampling event was completed on July 21.

To allow the examination of mixing (between areas and of marked and unmarked fish) throughout the study area and probabilities of capture, the study area was partitioned into five sections. This included the inlet creek, the outlet creek (Bridge Creek), and three similar-sized sections of the lake. Further stratification was possible based on gear types. The variety and extent of available habitat and physical conditions at the time of sampling directed uses of the various gear types and the method of deployment. Beach seine, fyke traps, gillnets, and hook-and-line gear types were available for use during each sampling trip.

Beach seines were used in lake and stream shallows during the first sampling event. Fyke traps were set along the margin of the lake in shoals during both sampling events, and frequently moved to allow greater uniformity of sampling effort around the lake. The fyke traps were set with shore leads and 50 to 150 ft wing leads that were 6 to 10 ft deep and composed of 3/8 inch or smaller woven nylon mesh. Fyke-trap sets were fished 24 h. Sampling mortality rates precluded use of gillnets during the first (marking) event, but during the second sampling event gillnets were used to capture fish in two distinct zones of the lake. Near the shoreline, gillnets were set perpendicular to shore and extended out into the lake. To better understand the mixing behavior of fish throughout the study area, offshore floating and sinking gillnets were used to supplement the near-shore netting (Taube et al. 1998). This method was used to determine if a portion of the trout population was not available to shore-based gears and if mixing occurred throughout the lake. Sinking experimental gillnets were 46 m (150 ft) long by 2.4 m (8 ft) tall and were composed of five mesh sizes distributed in 9 m (30 ft) panels. Clear monofilament mesh sizes included 13 mm (0.5 in), 19 mm (0.75 in), 25 mm (1.0 in), 34 mm (1.37 in), and 38 mm (1.5 in) stretched mesh. Additional sinking gillnets were identically sized, but had a single mesh size of either 19 mm (0.75 in) or 25 mm (1.0 in). The offshore floating gillnet was 46 m (150 ft) long by 4.8 m (15 ft) made up with 25 mm (1.0 in) mesh. In this sampling trip, two crews were used to deploy nets. Angling was used as a supplemental gear during the first sampling event primarily below the outlet in Bridge Creek where fish were concentrated for spawning. Hook-and-line gear included the use of egg patterns, commonly referred to as "glo-bugs" and flies representing aquatic invertebrates such as stonefly and mayfly nymphs. Hook sizes were purposely kept small to avoid size selective bias toward larger fish.

Rainbow trout sampled at Summit Lake during the late June sampling period were tagged, and given adipose finclips before release. To lessen the impacts of marking with anchor tags, small fine-fabric Floy™ FD-68b anchor tags were used. During the middle of July sampling period, unmarked fish were given a partial left pelvic finclip. When wind conditions and workloads permitted, trout were weighed to the nearest 1 g with a self-taring digital balance. Fish that were killed inadvertently were sampled for total weight, stomach content, determination of sex, and collecting of otolith.

DATA COLLECTION AND ANALYSIS

Data were electronically stored in data files (Appendix A). Following the field work, scale samples were sorted under a dissection microscope and several scales were cleaned and mounted between microscope slides. Because of the large number of scales collected at Summit Lake, 5 to 10 scales from each fish were directly mounted between slides without cleaning. Ages were determined by counts of annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Scale analysis and age determination of rainbow trout incorporated aging criteria developed by Beamish and McFarlane (1987), Dunaway (1993), and Minard and Dye (1998). Estimated age was determined by counting regions of the scales where circuli were broken or compacted. Age determination of steelhead was supplemented with methods and criteria from Jones (*Unpublished*) for determining and reporting ages with fall-run steelhead. For steelhead, scales without a completed spawning check were defined as initial or first time spawners. Fish with previous spawning checks were defined as repeat spawners. Spawning checks appeared on scales of repeat spawners as interruptions of the normal circuli growth as seen by absorbance or erosion at the scale margin during freshwater residence and spawning (Jones *Unpublished*). Completed spawning checks were indicated by resumption of circuli growth.

Age designation for steelhead is a modification from the European method to incorporate life history information on repeat spawning. For example, an assigned age of 3.2s is an age-5 spawner which: 1) spent 3 winters in fresh water prior to smolt emigration, and 2) returned to spawn in fresh water in October after two years at sea, (i.e. two winters at sea). The letter "s" represents a freshwater immigration (spawning event) and numbers represent years between events.

SAMPLE COMPOSITION ESTIMATES

Age and length data from rainbow and steelhead trout were used to estimate composition when feasible. The 1999 Gulkana River sampling field studies did not incorporate a mark-recapture experiment that would allow the examination and adjustment for sampling biases. These samples, however, are suitable for describing the catchable population, providing information to anglers, and comparing previous catch samples. Proportions of fish by age captured during a single sampling event were calculated as:

$$\hat{p}_k = \frac{y_k}{n} \quad (1)$$

where:

$\hat{p}_k$ = the proportion of rainbow or steelhead trout (hereafter referred to as "trout")that were age k;
y_k = the number of trout sampled that were age k; and,
n = the total number of trout sampled.

The variance of this proportion was estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}. \quad (2)$$

Length composition was estimated in a similar manner, replacing age class with 25-mm FL incremental-length classes.

MARK-RECAPTURE ASSESSMENT

The 1999 Summit Lake project incorporated a closed-model mark-recapture experiment to estimate the abundance of rainbow trout.

The assumptions necessary for accurate estimation of abundance in Summit Lake were (Seber 1982):

1. the population was closed (no change in the number of trout in the population during the estimation experiment);
2. all trout had same probability of capture in the marking sample, or in the recapture sample, or marked and unmarked trout mixed completely between marking and recapture events;
3. marking of trout did not affect their probability of capture in the recapture sample;
4. trout did not lose their mark between the marking and recapture events; and,
5. all marked trout were reported when recovered in the recapture sample.

For assumption 1, it is known that the Summit Lake population is closed to immigration by impassable physical barriers created in the outlet. For assumption 2, the sampling design for this project was established so that sampling periods would nearly duplicate the timing of spawning and the post-spawning summer feeding period. This resulted in a marking period during the spawning season when capture efficiency was high in the outlet area. The second sampling event started 14 days later, at a time when spawning fish had vacated the outlet area, entering the lake for feeding, and probable mixing. Finally, the study design incorporated the use of multiple gear types. The use of beach seines, hook and line, fyke traps, and gillnetting allowed fishing in different habitats (outlet and inlet streams, lake shoreline and shoals, open water and drop-off gillnetting). This allowed the marking of fish from all habitats, areas, and segments of the population (spawners and non-spawners) in both sampling events. This assumption was examined through comparison of the marked-to-unmarked ratios in catches from different areas and gears.

Validity of assumptions 2 and 3, relative to the effect of capture gear, were examined for both capture-induced behavior (i.e. gear avoidance or attraction) and size selectivity whenever possible. Three of the four gear types, however, were not fully utilized in both sampling events. Because of high levels of sampling mortality associated with gillnetting in the first sample, the use of gillnetting was discontinued in the first sampling event. We discontinued using beach seining after the fish dispersed from the spawning grounds, as well as hook-and-line gear when the availability of time became an issue in the second sampling event.

Relative to size selectivity by gear, a series of two-sample Kolmogorov-Smirnov (KS) tests were examined (Appendix A1). The first KS test compared the cumulative length frequency distributions of marked and recaptured trout. The second KS test examined the length frequency of fish captured during the first (marking) sample compared to fish captured in the second (recapture) sample. Since length stratification was necessary, the largest test statistic was used to delimit the data set into size strata. Because capture probabilities can differ significantly among areas, assumption 2 was examined by chi-square tests on recapture-to-catch ratios (R/C) and recapture-to-mark (R/M) ratios. Tests for consistency of a Petersen estimate were performed (Seber 1982).

Assumptions 4 and 5 were ensured by the sampling methods. Assumption 4 was ensured because all fish were double marked using a tag and a partial finclip, which could not grow back during the study. Assumption 5 was ensured through examination of all fish for tags and finclips.

Population estimates were generated based on the appropriate choices of strata (each size or area grouping) when necessary, before summing the independent estimates to yield an estimate of the entire population.

The number of rainbow trout in Summit Lake was estimated using the Chapman modified Petersen estimator (Chapman 1951). The population abundance estimate was calculated as:

$$\hat{N} = \frac{(n_2+1)(n_1+1)}{m_2+1} - 1 \tag{3}$$

where:

$\hat{N}$ = the abundance of rainbow trout in the Summit Lake study area;
n_1= the number of trout marked and released during the first event;
n_2= the number of trout examined for marks during the second event; and,
m_2= the number of trout recaptured in the second event.

Variance of this estimator was calculated as:

$$V[\hat{N}] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{4}$$

AGE AND LENGTH COMPOSITION IN THIS MARK-RECAPTURE ASSESSMENT

Age and length compositions were used to apportion the population estimate into age and length classes. Given the KS tests, age and length information collected during the marking sample, the recapture sample, or both samples may be used to calculate age and length composition.

Abundance was estimated for each length stratum j independently. Age and length data was then adjusted to minimize bias due to unequal capture probabilities by length.

To adjust age and length data, the proportion of fish in each age and length group was estimated by:

$$\hat{p}_{jk} = {}^{n_{jk}}\!/_{n_j} \quad (5)$$

where:

$\hat{p}_{jk}$ = the estimated proportion in length or age class k given length stratum j;

n_{jk} = the number sampled from length or age class k given length stratum j; and,

n_j = the number sampled in length stratum j.

The variance of $\hat{p}_{jk}$ is identical to equation 4 (with appropriate substitutions).

The estimated abundance of age or length class *k* fish in the population was then estimated as:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk}\hat{N}_j \quad (6)$$

where:

$\hat{N}_j$ = the estimated abundance in length stratum j; and,

s = the number of length strata.

The variance for $\hat{N}_k$ was approximated by the delta method (Seber 1982):

$$\hat{V}\left[\hat{N}_k\right] \approx \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + V\left[\hat{N}_j\right]\hat{p}_{jk}^2\right) \quad (7)$$

The estimated proportion of the population that were age or length *k* $(\hat{p}_k)$ was estimated as:

$$\hat{p}_k = \hat{N}_k / \hat{N} \quad (8)$$

where: $\hat{N} = \sum_{j=1}^{s}\hat{N}_j$

Variance of the estimated proportion was approximated using the delta method (Seber 1982):

$$\hat{V}[\hat{p}_k] \approx \sum_{j=1}^{s}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_{jk}\right]\right\} + \frac{\sum_{j=1}^{s}\left\{V\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2} \quad (9)$$

CONDITION FACTOR OF SUMMIT LAKE RAINBOW TROUT

When food resources are plentiful, the condition of individual fish in populations is often subjectively regarded as "better", "higher", or "more robust". In populations where food resources are limited, individuals sampled at the same time or biologically significant time period (spawning, post-spawning, mid- or post-feeding period, etc) and compared between years may be in poorer physical condition. The condition at a particular age was expressed with a calculation *a* of condition factor, which related the paired lengths and weights for individuals with an assumption of isometric growth (Everhart and Young 1981). The factor used to compare rainbow trout of Summit Lake was Fulton's condition factor *a* which is derived from the isometric growth equation (Ricker 1975):

$$a = \frac{w}{l^3} \qquad (10)$$

where:

w = the observed weight for an individual trout; and,

l = the observed length for an individual trout.

LIMNOLOGY OF SUMMIT LAKE

Food webs that have supported the past and current populations of rainbow trout have not been described or studied. It is thought that no other forage species of fish have been, or are available for rainbow consumption, however, cannibalism probably occurs. Previous growth rates for the trophy-sized rainbow trout in Summit Lake attest to the lake's ability to provide adequate, food resources. Invertebrate populations composed of a zooplankton community and aquatic invertebrates most likely provided the bulk of past and current food resources. It was learned that differing stocking densities of juvenile sockeye salmon into Alaskan lakes altered species composition and diversity of zooplankton and reduced the zooplankton biomass (Koenings and Kyle 1997). Anecdotal information on the history of Summit Lake included observations of a dense population of large shrimp, probably fairy shrimp *Eubranchipoda* sp. Other accounts listed snails as a food item for these trout.

During the stock assessment trips, the lake's limnology was examined through biological sampling and measurements of physical and chemical (water quality) parameters.

Biological Limnology

An examination of the biological limnology of Summit Lake was conducted during sampling to provide baseline information and to improve understanding about primary and secondary level food sources in relation to the trout population.

Primary Food Production:- Phytoplankton

Total chlorophyll-a was measured as an index of phytoplankton biomass, which is the primary production at Summit Lake. Phytoplankton were sampled directly from the water column by filtering a specified amount of water through a glass-fiber filter to collect algal cells. Chlorophyll-a was later extracted from the preserved filter to estimate the phytoplankton standing crop using rapid bioassessment techniques (Barbour et al. 1997).

Duplicate or triplicate 1 liter samples of lake water were taken at several offshore locations along the length of Summit Lake. Each water sample was filtered through a Gelman glass-fiber filter (GF A/E; 0.45 μm) with a hand vacuum pump at -20 lb pressure. Approximately 2 ml of $MgCO_3$ was added prior to the completion of filtering to prevent acidification of the sample. Each filter was folded in half, placed in a paper fiber filter for continued drying, placed in a whirl-pac with silica gel desiccant, and immediately stored in a light-proof container on ice before freezing.

In the lab, the filters were cut into small pieces and placed in a centrifuge tube with 10 ml of 90% buffered acetone to extract the chlorophyll. Centrifuge tubes were placed in a metal rack, covered with aluminum foil, and held in a dark refrigerator for 24 h. After extraction, samples from Summit Lake were read on a Turner Model 10 fluorometer. The Turner Fluorometer was calibrated with primary and secondary chlorophyll standards, using a Shimadzu UV-1601 spectrophotometer, according to standard methods (APHA 1992).

Secondary Level Food Production: Zooplankton

Zooplankton sampling was conducted during the second sampling trip to Summit Lake. During the early evening hours, quantitative zooplankton samples were collected using vertical tows at three locations located at the west, central, and east basins with depths ranging from 28 to 58 ft. The 0.5 m plankton net (230 μm-mesh) was pulled from depth at an approximate rate of 0.5 $m \cdot sec^{-1}$ to the surface. Zooplankton diversity samples over a range of depths and differing habitats (middle lake and near shore) were also gathered and preserved. This was accomplished by several 20 min oblique tows using the 0.5 m plankton net towed 50 to 100 ft behind a powered inflatable boat. By varying direction, motor speed, and weight through the addition of 4 and 8 pound lead weights to the tow-net harness, the sampling depths varied from the surface to ~ 20 ft. Samples were rinsed from the plankton net and collection cup using filtered lake water. These samples were preserved in the field in a 70% ethyl alcohol solution in Nalgene bottles and later transferred into a buffered 10% formalin solution for storage.

Zooplankton samples were later sampled and enumerated in the lab. Each sample was diluted to a volume of 400 ml, and a 5 ml subsample was drawn out of the stirred and resuspended sample using a 5 ml Hansen-Stemple pipette. Zooplankton was counted under a microscope on a gridded petri dish. Three replicate 5 ml subsamples were taken from each sample and counted independently. The counts of predominant zooplankton families composing the samples (Cladocerans and Copepods) were then summed for a total count per sample. Counts were then expanded by the dilution factor to estimates the full-sample abundance. Estimates of standing crop zooplankton density and biomass were estimated on a surface area basis since the lake volume of Summit Lake is unknown and to allow comparison with other lakes studied (Koenings and Kyle 1997; and S. Honold, Alaska Department of Fish and Game, Kodiak, personal communication).

Estimated zooplankton biomass was calculated using estimated zooplankton sample abundances, stabilized air-dried weights for predominant sampled size classes or families of zooplankton, and expansions from sample to surface area. Stabilized air-dried weights of 10 individual zooplanktors were performed using an Electrocahn™ microbalance to the nearest milligram (mg). Six replicate samples of 10 individuals were made for the 4 predominant groups observed in the samples, yielding average weights for each. Two size classes of Cladocerans (small and large) and two Copepod groups (a *Calanoid* sp. and a *Cyclopoid* sp.) were weighed in this manner. The average relative frequency of each group in the sample (ratio of Cladocerans to Copepods) was then applied to apportion the sample abundance. The sample biomass was estimated as a sum of products for each group-specific abundance and respective dry-weights. The overall estimated zooplankton biomass density was estimated on a basis of surface area (m^2) that avoided an assumption of equal vertical distributions of zooplankton (Koenings et al. 1987).

Qualitative zooplankton samples which were taken from oblique plankton tows were examined by staff at the University of Alaska Fairbanks in the Marine Sciences Department Invertebrate Sorting Laboratory. Staff examined aliquots of the samples under microscope to further characterize diversity of families or groups of zooplankton and pelagic invertebrates.

Secondary Level Food Production: Aquatic Invertebrates

Samples of aquatic invertebrates were gathered using a stationary drift net and kick nets in the outlet stream, Bridge Creek. In addition, stomach contents of sampled rainbow trout were collected, preserved in 70% ethyl alcohol, examined, and classified by family.

Physical and Chemical Limnology

Even though some water quality samples were taken in previous visits to Summit Lake (ADF&G *Unpublished*), we also took water quality samples. Water quality measurements included total alkalinity and hardness, dissolved oxygen (mg/l), pH, conductivity, and water temperature profiles.

To determine total alkalinity, H_2SO_4 was titrated using a Hach digital titrator to determine the colorimetric endpoint using phenolphthalein and bromocresol green-methyl red indicators. Results of the titration for total alkalinity was expressed in mg/L as $CaCO_3$. The measurement of total hardness was conducted in a similar manner using EDTA as the titrant. The results for total hardness were expressed as mg/L as $CaCO_3$ and magnesium [Mg] was determined by the difference between measurements of total hardness and total alkalinity.

Profiles of dissolved oxygen, pH, conductivity, and water temperature were measured from the lake surface to the lake bottom using a Hydrolab™ Surveyor 4 coupled to a Mini Sonde multiprobe. Water temperatures were collected using two Onset™ Optic Stowaway temperature data loggers over the duration of the study. Two temperature loggers were attached to a common anchored line, and were suspended at 3 and 18 feet beneath the surface to reflect temperatures above and below depths where thermal stratification could occur. The units were retrieved at the completion of stock assessment, and downloaded through an Onset™ Optic Shuttle through a RS 232 port to a personal computer for data analysis and archiving.

RESULTS

MIDDLE FORK GULKANA RIVER

The Middle Fork Gulkana River and Hungry Hollow Creek were sampled in 1999 during the spring spawning period.

On May 27, 1999, the crew of four traveled to Dickey Lake. The lake was still ice covered, and shelf or Aufeis accumulations along the Middle Fork ranged from 5 to 9 ft in thickness and covered the immediate valley floor along a two-mile stretch of the river. On May 28, the crew conducted a foot survey throughout a 3-mi section used by spawning trout. Water temperatures were consistently 2.5 °C. The high ice-shelf bordering the river enabled enhanced visibility of fish over approximately two-thirds of the spawning area and aided in locating fish for sampling. Fish were observed moving and holding in several locations, but no spawning activity was noted. In several locations ice blocked the river channel, which caused the flow to be diverted overland through adjacent low-lying willow scrub. In one of these areas 14 trout were observed moving upstream through the flooded willows. Based on these observations, we concluded that the onset of sampling corresponded to the time pre-spawners entered the area to accumulate immediately before spawning.

After a rise in water temperatures to 4 °C, spawning activity began. Catch rates improved at this time. Prior to spawning activity, fish were skittish in the shallow waters, and were easily spooked. The use of a beach seine was unsuccessful in capturing fish prior to the onset of spawning and its use was discontinued during spawning to avoid disturbing spawned eggs. Hook-and-line catches also improved with increased spawning activity because fish focused on spawning and could be more easily approached. Between May 28 and June 1, we sampled 15 steelhead and 20 resident rainbow trout. On the morning of June 1, we visually counted 45 fish in spawning concentrations, but it was likely that more fish were present. We could more easily see the larger fish compared to the smaller rainbow trout, since larger fish dominate the spawning activities.

Lengths of sampled resident rainbow trout ranged from 395 to 660 mm FL and of sampled steelhead between 584 and 900 mm FL. The median-size resident rainbow trout was 520 mm FL, and steelhead 725 mm FL. Ages of sampled rainbow trout ranged from 4 to 10 years (Table 2), and age-groupings of steelhead included 3.1, 3.2, 3.3 and 4.2 (Table 3). The examination of scale patterns from 15 steelhead indicated that all were first-time spawners. Median ages were 6 for rainbow and 3.2 for steelhead. During sampling, 2 previously tagged resident trout were recovered. A trout with tag number #44158 was originally tagged in the spawning area of the Middle Fork in June 1998. At that time it was 530 mm FL and estimated age-8. At recovery, it was 570 mm FL and age-10. A trout with tag number #44215 was originally tagged in the canyon area of the mainstem of the Gulkana during July 1998. At that time it was 630 mm FL and age-7. At recovery, it was 660 mm FL and age-8. Later, an angler reported capturing this fish again at the site of original tagging during July 1999.

Hungry Hollow Creek

On June 2, water conditions were low, clear, and with water temperatures between 4 and 5 °C. Weather conditions varied between rain, hail, and snow showers. No fish were captured or seen in the upper half of the survey area. Approximately 1 mi below Wait-a-Bit Lake, we observed and began to catch trout. The crew sampled downstream 2 mi to a location 8 mi above the confluence of the Middle Fork Gulkana River. At the lower-most sampled area, one spawning group was located and about 10 other fish were seen passing upstream. A total of 10 fish were sampled. These included 4 steelhead and 6 resident rainbow trout. One of these rainbow trout was a fish originally tagged in 1998. The timing of sampling at Hungry Hollow was early in relation to past spawning distributions (Stark 1999, Fleming 1999) which was based on the observation of fish passing upstream near the lower end of the sampled area.

Lengths of resident rainbow trout ranged from 335 to 560 mm FL, and of sampled steelhead between 570 and 770 mm FL. Ages of sampled rainbow trout ranged from 4 to 6 years, and age-groupings of steelhead were 3.2 and 3.2s1. The low number of fish sampled at Hungry Hollow precluded meaningful estimates of length and age composition. Information on sampled fish from Hungry Hollow Creek included:

Table 2.-Sample sizes, estimated proportions, and standard errors by age class and 50 mm FL incremental size groupings for rainbow trout (≥150 mm FL) captured from the Middle Fork Gulkana River, May 28 through June 1, 1999.

Age	n	$\hat{p}$[a]	SE[b]	Length[c]	n	$\hat{p}$[a]	SE[b]
				175	0	0.00	0.00
3	0	0.00	0.00	225	0	0.00	0.00
				275	0	0.00	0.00
4	1	0.06	0.06	325	0	0.00	0.00
				375	1	0.05	0.05
5	2	0.11	0.08	425	3	0.15	0.08
				475	3	0.15	0.08
6	7	0.39	0.12	525	7	0.35	0.11
				575	4	0.20	0.09
7	4	0.22	0.10	625	1	0.05	0.05
				675	1	0.05	0.05
8	3	0.17	0.09	725	0	0.00	0.00
				775	0	0.00	0.00
9	0	0.00	0.00	825	0	0.00	0.00
				875	0	0.00	0.00
10	1	0.06	0.56	925	0	0.00	0.00
				975	0	0.00	0.00
Totals	18	1	---	Total	20	1.00	----

[a] $\hat{p}$ = proportion of rainbow trout in the sample.

[b] SE = standard error of the proportional contribution.

[c] Length = midpoint of 50 mm length class for rainbow trout in the sample.

Table 3.-Sample sizes, estimated proportions, and standard errors by age class and 50 mm FL incremental size groupings for steelhead (≥150 mm FL) captured from the Middle Fork Gulkana River, May 28 – 31, 1999.

Age[a]	Count	$\hat{p}$[b]	SE[c]
2.3[c]	1	0.07	0.07
3.1	1	0.07	0.07
3.2	9	0.60	0.13
3.3	3	0.20	0.11
4.2	1	0.07	0.07
Totals	15	1	---

Length[d]	Count	$\hat{p}$[a]	SE[b]
175	0	0.00	0.00
225	0	0.00	0.00
275	0	0.00	0.00
325	0	0.00	0.00
375	0	0.00	0.00
425	0	0.00	0.00
475	0	0.00	0.00
525	0	0.00	0.00
575	1	0.05	0.06
625	1	0.05	0.06
675	3	0.15	0.09
725	3	0.15	0.09
775	3	0.15	0.09
825	3	0.15	0.09
875	0	0.00	0.00
925	1	0.05	0.06
975	0	0.00	0.00
Total	15	1.00	----

[a] $\hat{p}$ = proportion of steelhead trout in the sample.

[b] SE = standard error of the proportional contribution.

[c] These age designations used for steelhead are a modification from the commonly used European designation to incorporate life history information on repeat spawning. For example: a steelhead designated as 3.2 would be interpreted as 3 freshwater winters, followed by 2 saltwater winters. A fish designated as 3.2s or 3.2s1 would indicate a steelhead that is, or will be a repeat spawner.

Tag Number	Date	Type/Form	FL (mm)	Sex	Age	Capture Location
44027	6/2/99	Steelhead	570	M	3.1	~1.25 mi below Wait-a-Bit Lk
44026	6/2/99	Steelhead	770	F	R.1SS	~1.25 mi below Wait-a-Bit Lk
44314	6/2/99	Steelhead	684	F	3.2	~5.5 mi below Wait-a-Bit Lk
44313	6/2/99	Steelhead	680	F	3.2	~5.5 mi below Wait-a-Bit Lk
44028	6/2/99	rainbow	495	M	6	~1.25 mi below Wait-a-Bit Lk
44025	6/2/99	rainbow	560	M	6	~1.0 mi below Wait-a-Bit Lk
44024	6/2/99	rainbow	465	M	5	~1.0 mi below Wait-a-Bit Lk
44023	6/2/99	rainbow	460	M	6	~1.0 mi below Wait-a-Bit Lk
44059	6/2/99	rainbow	335	M	4	~1.0 mi below Wait-a-Bit Lk
44312	6/2/99	rainbow	538	M	6	~5.5 mi below Wait-a-Bit Lk

Aerial Surveys and Detection of West Fork Spawning Areas

On May 30, aerial surveys of several tributaries or portions of the west fork of the Gulkana River were unsuccessful. Flying south from Dickey Lake, stream conditions of the headwaters of Victor Creek were high and muddy. Flying further up the West Fork, water conditions were muddy in the three remaining survey locations: Keg and Moose Creeks, and the north branch of the West Fork. As a result of poor conditions, the surveys along the West Fork were discontinued. Aerial surveys at two Middle Fork spawning areas were considered unsuccessful because of heavy winds and poor lighting conditions. Nonetheless, nine fish were counted below Dickey Lake and in Hungry Hollow Creek.

SUMMIT LAKE

On June 24, the first day of the marking event, Summit Lake was ice free and water temperatures of the lake surface and in Bridge Creek ranged between 8 and 10 °C. The timing of the marking event, corresponded to a time when many trout were concentrated for spawning. The recapture event, began on July 16. The timing of the second sampling event corresponded to the post-spawning summer-feeding period. Surface water temperatures during the marking event ranged between 8 and 12 °C, and 13 and 15 °C during the recapture event. Each sampling event included 6 days of sampling.

Sampling was initiated in the outlet stream, Bridge Creek, where visual counts indicated 2,000 or more trout present. The crew used hook-and-line to capture 225 fish and beach seines to capture 462 fish in Bridge Creek (Table 4). Both gears were fished from the lake outlet to a location 600 ft downstream. This area included nearly all of the area used by spawning trout, but could not be used in areas further downstream where the channel became incised, swift, and confined between cutbanks with thick stands of willow. Beach seines were also used in several locations around the lake in shoal areas. These areas included windward shoals near the outlet end of the lake, and a shoal near an inlet stream at the west end of Summit Lake (Figure 3). Beach seining within the lake was conducted during the marking event only.

During the marking event, gillnetting was discontinued after 18 of 22 (82%) trout captured in 9 sets (5.5 net hrs) were killed or significantly injured. Furthermore, gillnetting was relatively inefficient when compared to the other gears during this sampling event. Gillnet gear was used

Table 4.-Capture probability, recapture rate and distribution of recaptured rainbow trout ≥130 mm FL by gear type in the Summit Lake mark-recapture experiment, June 26 through July 22, 1999.

		Recapture Gear:				
Marking Gear	Marks	Fyke	Seine	Hook and Line	Gillnet	R/M[a]
Fyke	606	82	0	0	4	0.13
Seine	462	30	0	0	3	0.06
Hook and Line	225	9	0	1	1	0.04
Gillnet[b]	0	0	0	0	0	0.00
Total	1,293	121	0	1	8	0.09
	Examined without marks=	1,217	0	12	231	
	R/C[c]=	0.09	0.00	0.07	0.03	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] Gillnetting conducted in the marking event was discontinued as a marking gear, and later mark-recapture data from gillnetting was removed from the study.

[c] R/C = capture probability, number of recaptures divided by number of fish examined in second event.

in the recapture event primarily to evaluate mixing of marked and unmarked fish particularly between onshore and offshore (surface and deeper) areas.

A total of 239 trout were caught in the recapture event by gillnet from 37 sets, which included 17.6 net-hours soak time. This included the recovery of nine marked fish. Capture probabilities (R/C) for gillnetting was lower than fyke traps (Table 4; $\chi^2 = 5.12$, df = 1, P = 0.02). Recapture rates (R/M) could not be assessed since no fish were marked using gillnets. The capture histories of eight recovered fish did indicate movements from various locations around the lake.

Fyke traps effectively allowed sampling effort to be geographically distributed around the perimeter of the lake (Figure 3). During the mark event, eight fyke-trap sets were placed at various locations around the lake, each for 24 h. A total of 606 trout ≥ 130 mm FL were marked and released alive. During the recapture event, 17 fyke-net sets resulted in the catch and examination of 1,338 trout ≥ 130 mm FL. This sample included the recovery of 121 tagged trout from the marking event. Hook-and-line gear was used more during the marking event than in the recapture event. Only 13 fish were captured using hook-and-line during the recapture event. These were pooled with fyke trap data.

During the mark-recapture experiment, a total of 82 trout died as a result of capture related injuries, and of these 52 were from gillnetting. The number of unique fish handled in the study was 3,486 fish, which included fish < 130 mm FL that were captured and released without marks. The lengths of all captured fish ranged from 62 to 455 mm FL. The overall mortality rate was 0.02 (2%). The total catches of trout ≥ 130 mm FL included in the mark-recapture experiment were 1,293 marked, and 1,351 examined for marks, which included 122 recaptured trout.

During the marking event sexual maturity was assessed by the presence of sex products. Mature males ranged from 120 mm FL to 388 mm FL (mean = 240 mm FL; n = 414 fish), and mature females ranged from 170 mm FL to 392 mm FL (mean = 300 mm FL, n = 203 fish). Mature males were generally darker in coloration, included a medial red stripe, and an olive green or brown background color over their bodies. Parr marks were observed on many of the smaller mature males. The coloration of spawning females differed by the presence of a silver background and lower spotting density. Based on dissection of mortally injured fish, sexually immature fish were found in all size classes, and many of the larger trout captured in gillnets in offshore and deeper areas were sexually immature males and females. The coloration of these fish included a bright silver background, discrete spotting, and coloration more similar to a bright condition salmon. This coloration pattern was consistent among all dissected fish that were sexually immature. No attempt was made to conduct separate estimates of male and female trout because sexual maturity could not be assessed during the second sampling event.

Abundance Estimation

Although various gear types were used, fyke traps were the primary gear in both sampling events. Beach seines and hook-and-line were pooled with fyke-trap caught fish. Gillnet caught fish were removed from the study.

Kolmogorov-Smirnov (KS) tests of cumulative length frequencies implied capture probabilities by size were different during the second sampling event (Figure 4A; D = 0.37, P < 0.01) and size

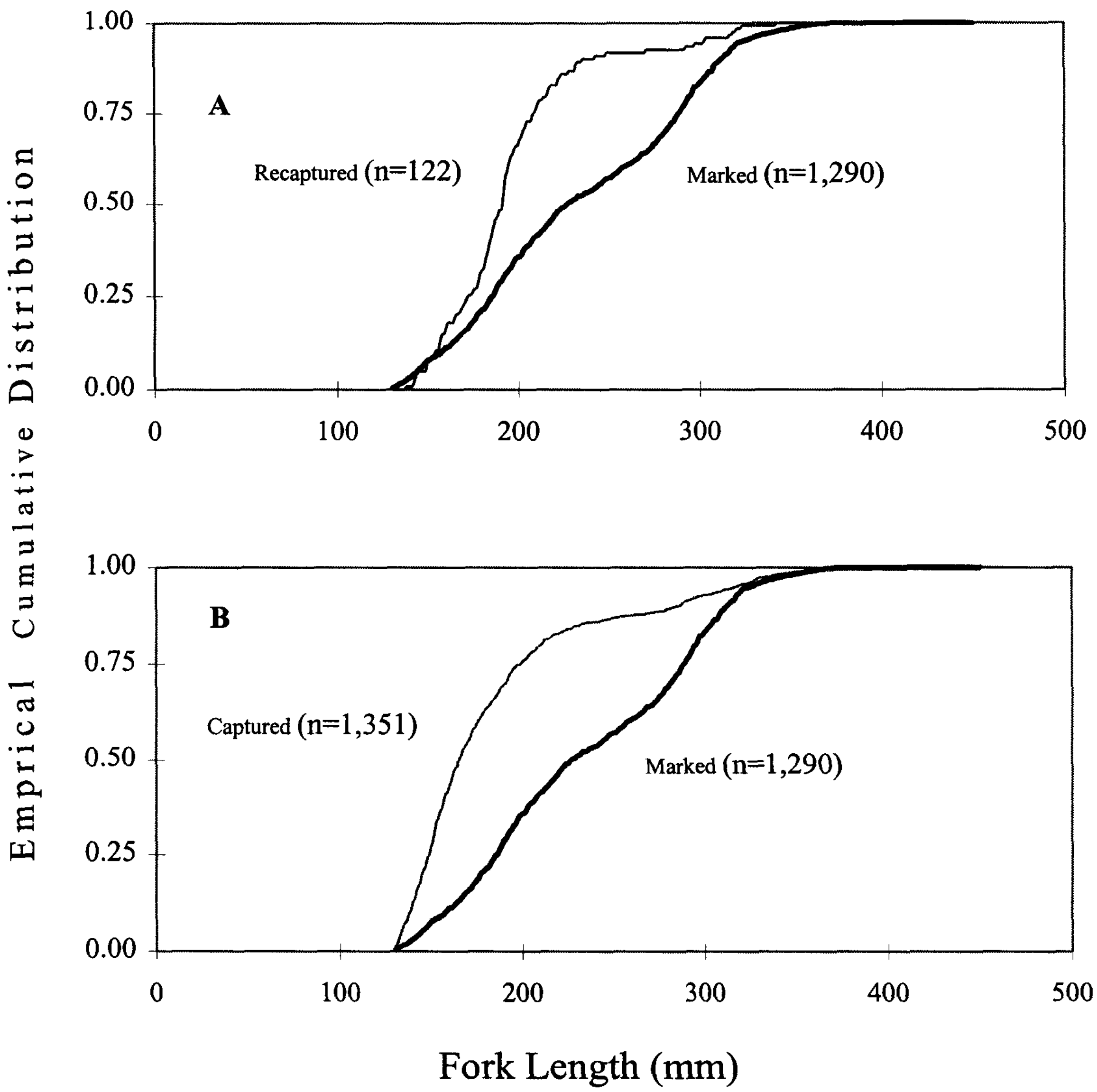

Figure 4.-Empirical cumulative distributions of lengths of rainbow trout marked versus lengths of rainbow trout recaptured (A); and, versus lengths of rainbow trout examined for marks (B) in Summit Lake, June 25 through July 1, and July 16-22, 1999.

selectivity could not be determined during the first event (Figure 4A; D = 0.43, P < 0.01). Given the differences in capture probabilities by size, size strata were determined at the length where maximal differences in recapture-to-catch ratios occurred (D_{218mm} = 0.37, P < 0.01). Each of the two size strata was examined using the three tests for consistency (Seber 1982). Since at least one test was not significant, the tests supported use of the Petersen estimator for the small fish stratum (Tables 5, 6, 7) and large fish stratum (Tables 8, 9, 10) without area stratification.

Size-Stratum	Mark M	Catch C	Recap R	R/M Ratio	Abundance N-hat	Standard Error	CV
130 to 217 mm	580	1,119	100	0.17	6,442	553	
≥ 218 mm FL	716	234	22	0.03	7,325	1,397	
Total	1,296	1,353	122	----	13,767	1,502	10.9%

The stratified estimate of abundance of rainbow trout (≥ 130 mm FL) in the 320 acre study area indicated an estimated density of 46 fish per acre.

Age and Size Composition

Scale samples were collected from rainbow trout during the second sampling event. Ages were determined for 877 fish. Ages were not determined for 57 fish from the sampled second event scales because the samples were regenerated or otherwise unreadable. In addition, ages were determined from scale samples taken from trout smaller than 130 mm FL to better understand size, age, and growth. Determined ages for rainbow trout at Summit Lake ranged from 1 to 8 years for fish ranging from 86 to 455 mm FL. Age composition estimates only include individuals that were ≥ 130 mm FL (Table 11).

After removing all gillnet captured fish from the study, the remaining age sample included 665 fish ≥ 130 mm FL. Because capture probability within age sampling was different without the second sampling event, estimates of size and age composition were adjusted. The predominant age class present was age-2 (35%) followed by age-5 fish (20%) and age-3 fish (17%; Table 11).

The-median size trout was 227 mm FL during the marking event and 175 mm FL during the recapture event. The Summit Lake assessed rainbow population was predominated by trout less than 12 inches (Figure 5). Since no trout were larger than 455 mm FL, the estimate of fish ≥ 32 inches (≥ 810 mm FL) was zero.

In addition to estimating the size composition, live-wet weights were measured from 222 trout during the second sampling event. This information was then used to estimate condition factor. Estimates of Fulton's condition factor ranged from 0.56 to 1.12, and averaged 0.91. Although no previous measurements from Summit Lake were available for comparison, there was a limited 1998 sample of condition factor estimates taken from a riverine population of rainbow trout in the Gulkana River. The condition factors from 24 fish sampled ranged from 0.96 to 1.64, and averaged 1.20 (Figure 6). When average weights for 20 mm FL size classes were applied to the size-apportioned abundance a crude estimate of rainbow trout biomass was 1,934 kg. The biomass density (biomass/surface area) was estimated as 14.8 kg per Hectare.

Mean lengths at age were also estimated for fish sample at Summit Lake in 1999. Previous age-length data and mean length at age estimates were also gathered or calculated from field notes and archived AWL data files. Estimates of historic and current mean length at age indicated a

Table 5.-Numbers of recovered and not recovered small strata rainbow trout (< 218 mm FL) marked in areas A, B, and C, corresponding to the Eastern, Central and Western areas in the 1999 Summit Lake stock assessment.

	Recovery History[a]				
Marking Area	A	B	C	Not Recovered	Total
A	64	14	6	373	457
B	5	0	1	46	52
C	4	2	4	61	71
Total	73	16	11	480	580

[a] $\chi^2 = 11.82$, df = 6, P = 0.06

Table 6.-Numbers of marked small strata rainbow trout (< 218mm FL) recovered and not recovered during the recapture event by areas A, B, and C corresponding to the eastern, central and western areas in the 1999 Summit Lake stock assessment.

	Marking Area			
Sampling History[a]	A	B	C	Total
Recovered	84	6	10	100
Not Recovered	373	46	61	480
Total	457	52	71	580
R/M ratio	0.18	0.11	0.14	0.17

[a] $\chi^2 = 2.09$, df = 2, P = 0.35

Table 7.-Numbers of marked and unmarked small strata rainbow trout (< 218mm FL) captured during the recapture event by areas A, B, and C corresponding to the eastern, central and western areas in the 1999 Summit Lake stock assessment.

	Marking Area			
Sampling History [a]	A	B	C	Total
Marked	73	16	11	100
Unmarked	770	135	114	1,019
Total	843	151	125	1,119
R/C ratio	0.09	0.10	0.09	0.09

[a] $\chi^2 = 0.59$, df = 2, P = 0.74

Table 8.-Numbers of recovered and not recovered large strata rainbow trout (≥ 218 mm FL) marked in areas A, B, and C, corresponding to the eastern, central and western areas in the 1999 Summit Lake stock assessment.

	Recovery History [a]				
Marking Area	A	B	C	Not Recovered	Total
A	8	3	4	553	568
B	0	3	1	66	70
C	0	3	0	75	78
Total	8	9	5	694	716

[a] $\chi^2 = 14.89$, df = 6, P = 0.02

Table 9.-Numbers of marked large strata rainbow trout (≥ 218mm FL) recovered and not recovered during the recapture event by areas A, B, and C corresponding to the eastern, central and western areas in the 1999 Summit Lake stock assessment.

	Marking Area			
Sampling History[a]	A	B	C	Total
Recovered	15	4	3	22
Not Recovered	553	66	75	694
Total	568	70	78	716
R/M ratio	0.03	0.06	0.04	0.03

[a] $\chi^2 = 0.34$, df = 2, P = 0.34

Table 10.-Numbers of marked and unmarked large strata rainbow trout (≥ 218mm FL) captured during the recapture event by areas A, B, and C corresponding to the eastern, central and western areas in the 1999 Summit Lake stock assessment.

	Marking Area			
Sampling History[a]	A	B	C	Total
Marked	8	9	5	22
Unmarked	69	92	51	212
Total	77	101	56	234
R/C ratio	0.10	0.09	0.09	0.09

[a] $\chi^2 = 0.13$, df = 2, P = 0.93

Table 11.-Sample sizes, sampled and adjusted proportions[a], estimated abundances by age class, and associated standard errors for Summit Lake rainbow trout (≥130 mm FL), July 16 through 22, 1999.

		Unadjusted Proportions		Adjusted Proportions					
Age	n	p	SE[p]	p'	SE[p']	CV[p']	n-HAT	SE[N-hat	CV[N-hat
1	43	0.06	0.01	0.04	0.01	18%	547	92	17%
2	374	0.56	0.02	0.35	0.04	11%	4,828	431	9%
3	112	0.17	0.01	0.17	0.02	11%	2,293	342	15%
4	48	0.07	0.01	0.15	0.02	16%	2,045	456	22%
5	59	0.09	0.01	0.20	0.03	14%	2,718	587	22%
6	24	0.04	0.01	0.08	0.02	21%	1,106	294	27%
7	4	0.01	0.00	0.01	0.01	50%	184	96	52%
8	1	0.00	0.00	0.00	0.00	100%	46	46	100%
9	0	0.00	0.00	0.00	0.00				
10	0	0.00	0.00	0.00	0.00				
11	0	0.00	0.00	0.00	0.00				
total:	665						13,767		

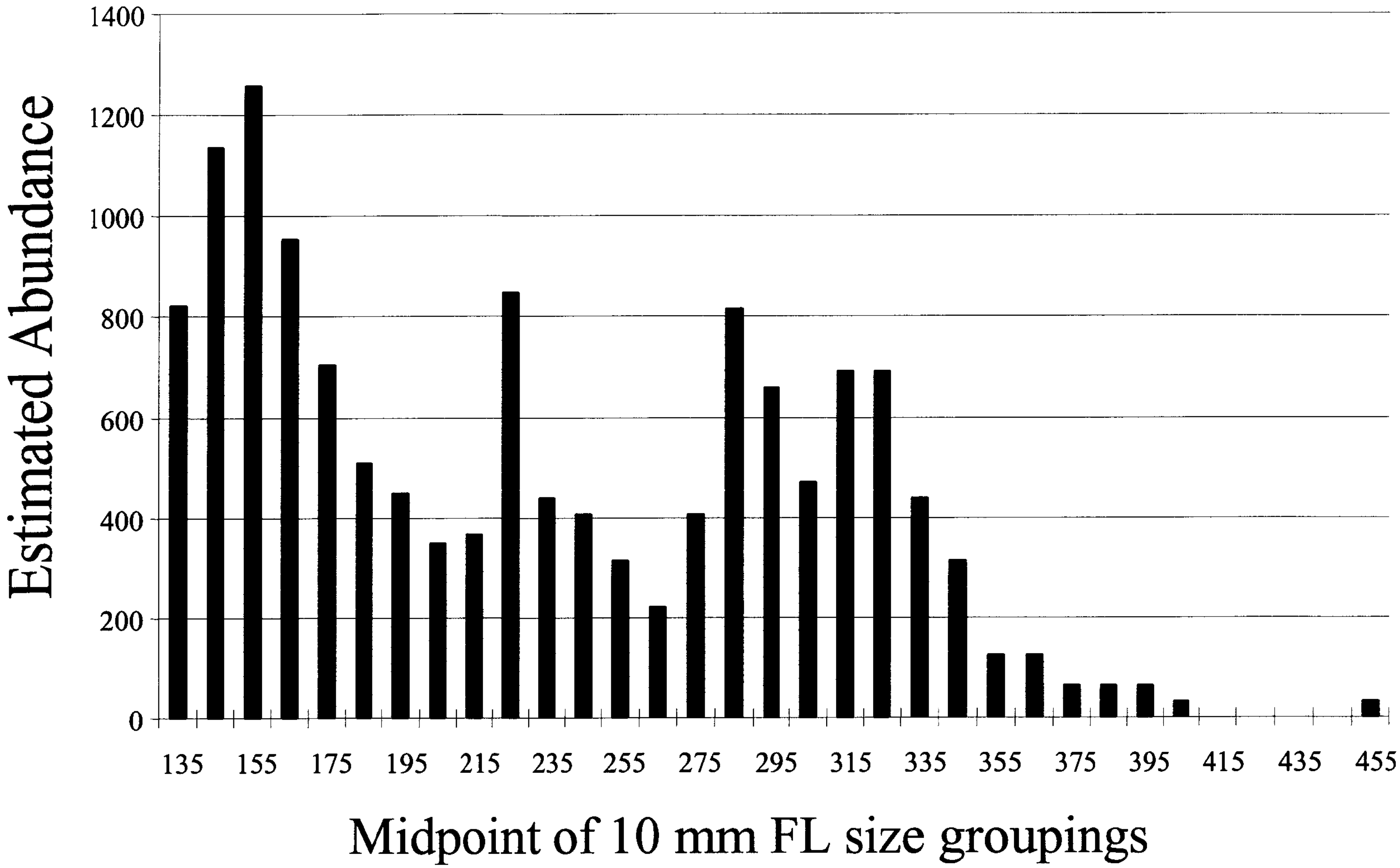

Figure 5.-Estimated abundance of rainbow trout by length ≥ 130 mm FL in Summit Lake, July 1999.

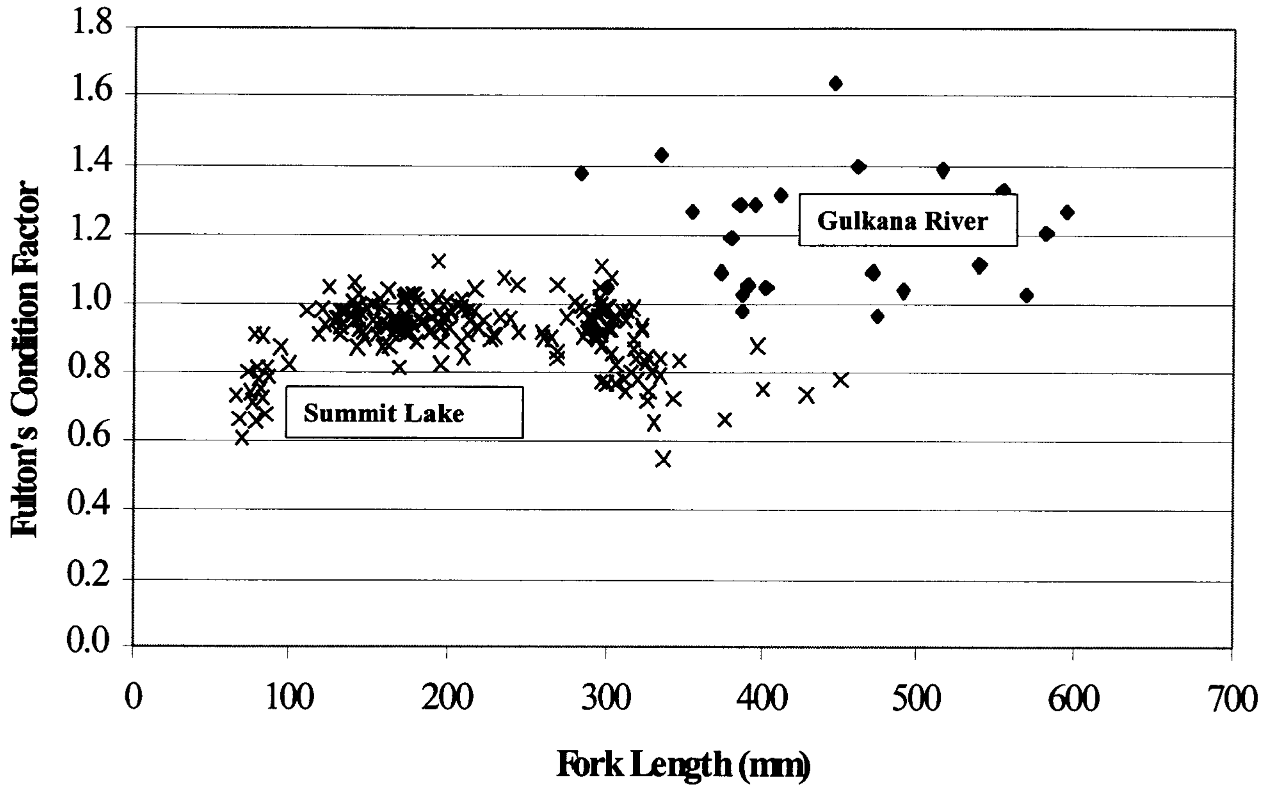

Figure 6.-Plotted estimates of Fulton's condition factor calculated from paired lengths and weights for summer feeding rainbow trout at Summit Lake during July 1999 (n = 202), and in the Gulkana River, July 1998 (n = 24).

decline in growth over 15 to 16 years (Figure 7). Sequential plots of length samples also indicated the loss of large trout from the Summit Lake population over the same time (Figures 8 and 9). Mean length at age data summaries from the current year and previous years are located in Appendix B.

Limnology

A preliminary examination of the food web and the physical and chemical nature of Summit Lake was conducted to collect information on factors that play a role in the current rainbow trout population dynamics. However, the samples that were collected in 1999 were not adequate to fully describe the Summit Lake ecosystem, since only a short time of the year was represented.

Primary Production

The results of phytoplankton sampling conducted at three stations indicated that very low levels of chlorophyl-a were present in the middle of July.

Secondary Production: Zooplankton

Quantitative and qualitative zooplankton sampling was conducted on July 21, 1999. Vertical and oblique tow netting samples of zooplankton were gathered to estimate biomass and to examine the diversity of zooplankton available in the lake at differing depths and proximity to the littoral zone near the lakes shoreline. These samples indicated the presence of two types of zooplankton: Cladocera and Copepoda (J. Sweetman, Institute of Marine Science, University of Alaska Fairbanks, personal communication). Within the order Cladocera, there were two species *Bosmina longirostris* and *Daphnia longiremis*. Within the subclass Copepoda there were also two species: *Cyclops columbianus* and *Diaptomus pribilofensis*.

Microscope counts of zooplankton from the quantitative vertical pulls or tows resulted in estimates of organisms per square meter of lake surface ranging from 1,496 in the outlet to 13,515 in the lake (Table 12). Since the outlet areas of lakes are often not considered as representative of the whole lake (S. Honnold, Alaska Department of Fish and Game, Commercial Fish Division, personal communication), the results are presented with (all areas) and without inclusion of the outlet sample (reduced).

Estimates of zooplankton biomass available in Summit Lake as a food resource for the rainbow trout population were calculated to compare with other lakes in Alaska (Koenings and Kyle 1997). The zooplankton samples were classified at the time of counting into Cladoceran and Copepod categories or groupings. The Cladoceran group included the smaller *D. longiremis* (~0.6 mm) and larger *B. longirostris* ~1.2 mm which were equally represented in the sample. The Copepod group consisted of Calanoids *D. pribilofensis* (1.2 mm) and Cyclopoids *C. columbianus* (1.0 mm) which were also equally represented in the sample, and were of roughly similar sizes (1.2 mm and 1.0 mm). The Cladoceran group was estimated to be 4.34 times more numerous when all areas were included, and 5.75 times more numerous when the outlet sample was removed. Stabilized dry weights for each of the zooplankton subgroups and the estimated sample abundances were used to generate estimates of biomass density at the time of sampling.

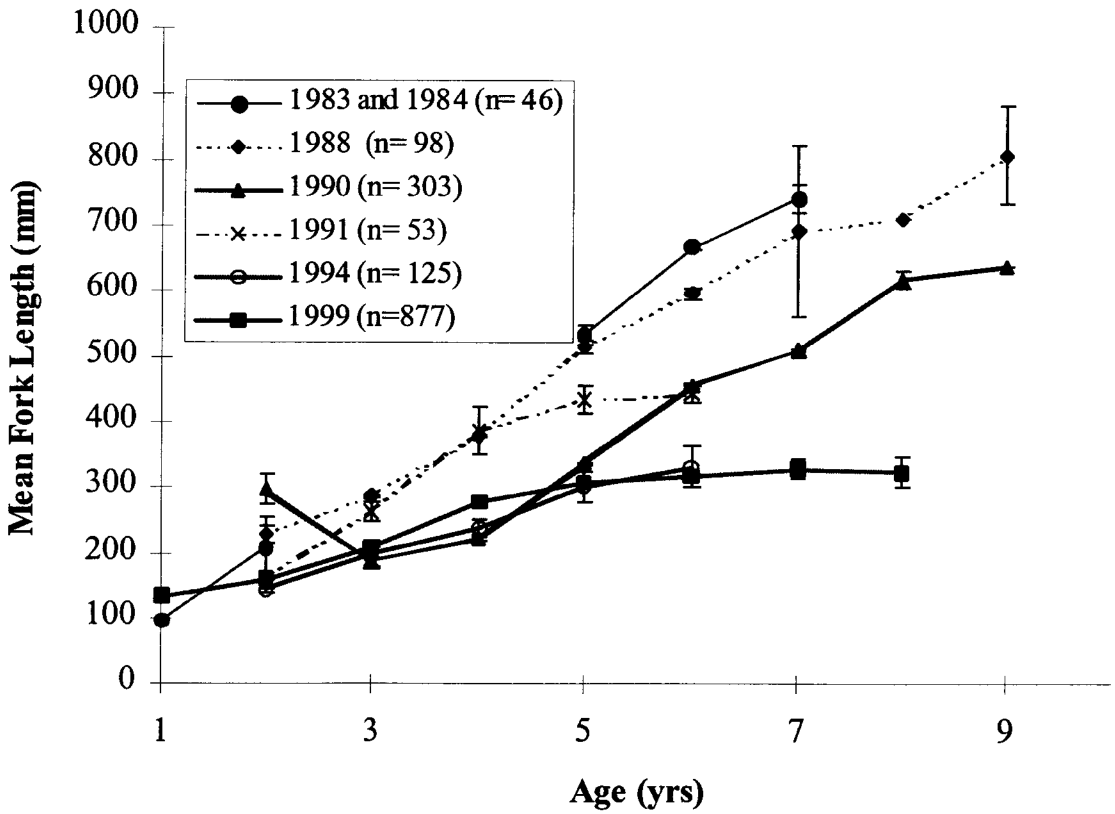

Figure 7.- Mean length at age estimates with 95% confidence intervals for Summit Lake rainbow trout sampled in 1983-84, 1988, 1990, 1991, 1994, and 1999.

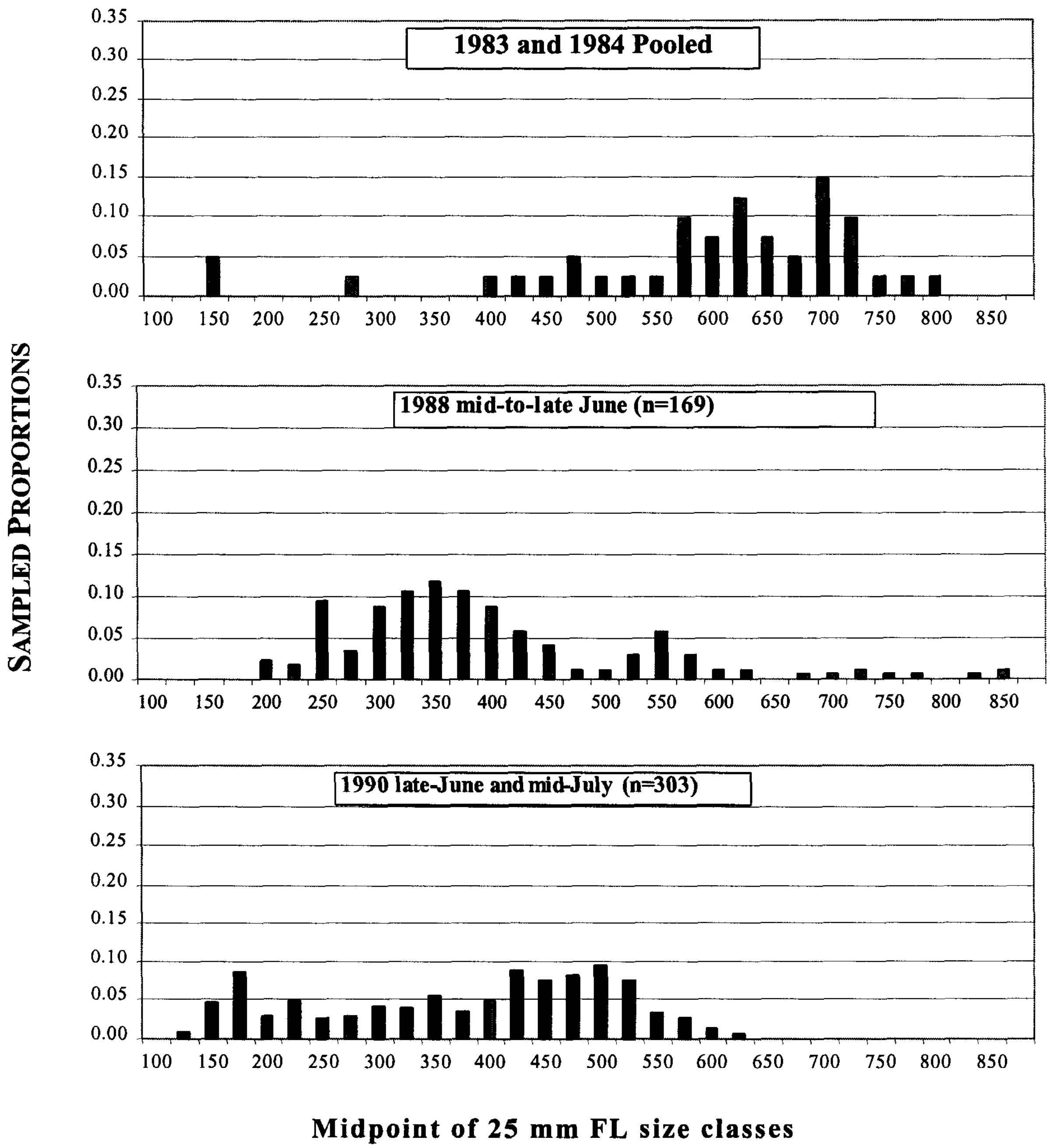

Figure 8.-Estimates of sampled proportions of rainbow trout by length for fish sampled at Summit Lake during stock monitoring conducted during 1991, 1994, and pooled samples collected during stock assessment in 1999.

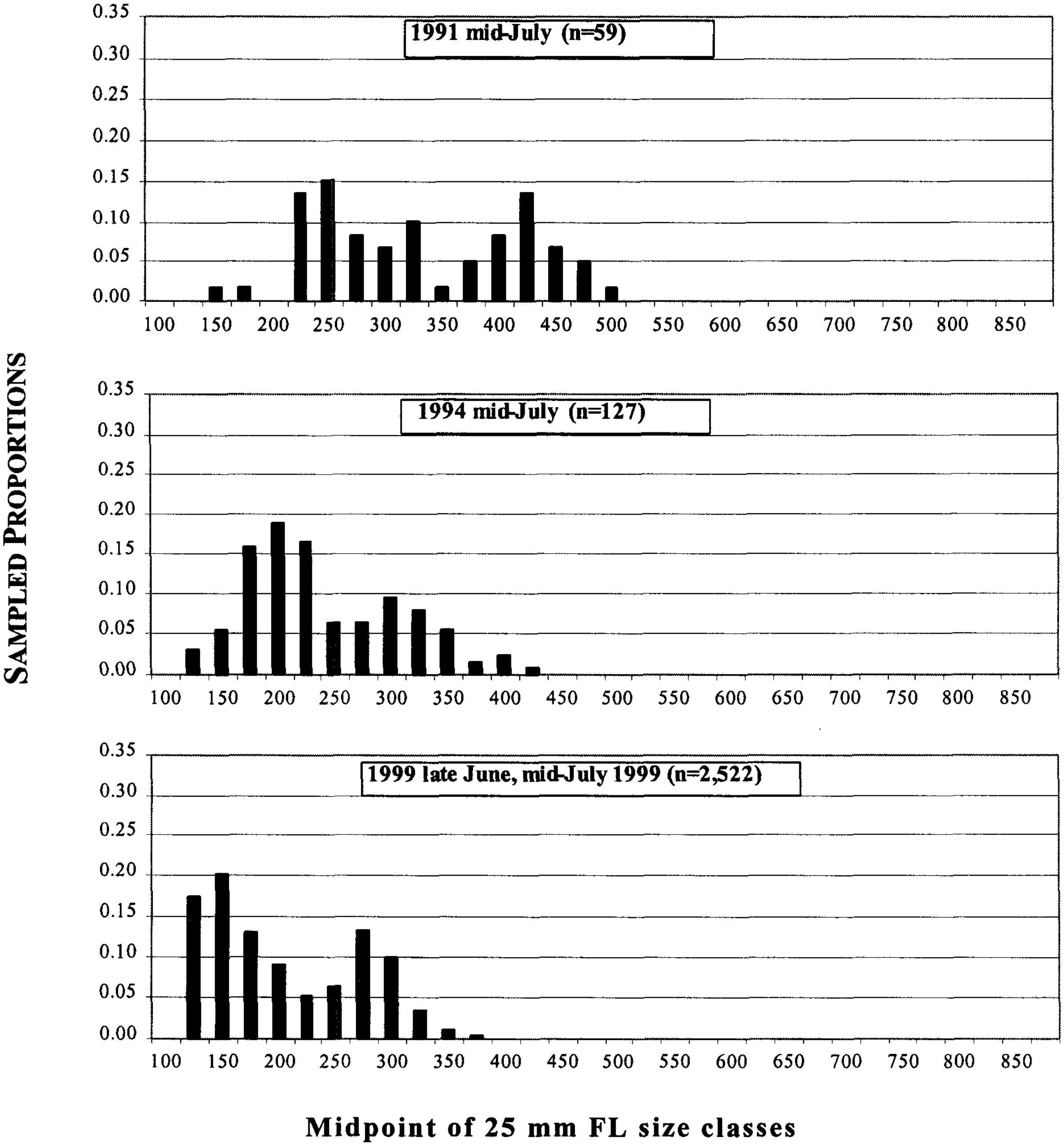

Figure 9.-Estimates of sampled proportions of rainbow trout by length for fish sampled at Summit Lake during stock monitoring conducted during 1991, 1994, and pooled samples collected during stock assessment in 1999.

Table 12.-Counts of microzooplankton sampled and estimated density of zooplankton in three areas of Summit Lake, July 1999.

Class	Microscope Counts #1	#2	#3	#4	Average	Estimated Total Density
West (58 ft)						
Calanoid-Cyclops	17	20	22	nd	20	
Cladoceran	114	119	106	nd	113	
Total	131	139	128	Nd	133	13,515 per m^2
Center (54 ft)						
Calanoid-Cyclops	18	17	15	nd	17	
Cladoceran	88	100	100	nd	96	
Total	106	117	115	Nd	113	11,478 per m^2
East (28 ft, outlet)						
Calanoid-Cyclops	18	4	13	22	14	
Cladoceran	25	14	17	31	22	
Total	43	18	30	53	36	1,496 per m^2

Sample Group:	Stabilized dry Weight (mg)	Zooplankton Biomass Density (mg/m^2): all areas	Reduced[a]
large cladoceran	0.023	391	580
small cladoceran	0.002	138	205
calanoid	0.006	28	31
cyclopoids	0.002	24	27
Total:		582	843

[a] Reduced refers to inclusion of samples from the Western and Central basin, only. This reflects productivity of the deeper lake basins, while the shallow outlet area was not deemed representative.

The estimates of biomass density (mg/m^2) at Summit Lake on July 21 may have corresponded to the time close to, or at peak seasonal zooplankton abundance. In order to compare data and results from Summit Lake to seasonal average biomass estimates from other studies, the estimates were reduced by 25% and 60% to offset bias from the sample timing and lack of replicate sampling throughout the season (S. Honnold, ADF&G Commercial Fisheries Division, personal communication). The resulting adjusted estimates of all areas ranged from 233 to 436 mg/m^2, and the reduced estimate (without the outlet area) ranged from 337 to 632 mg/m^2.

Secondary Production: Aquatic Invertebrates

Qualitative samples of other invertebrate food resources were collected from drift net and kick nets in Bridge Creek and from the stomachs of trout. The families of invertebrates identified included Midges (Chironomidae), Black flies (Simulidae), Stoneflies (Nemouridae), Mayflies (Baetidae), Caddisflies (Limnephilidae), and scuds (Amphipoda). No detailed analysis has been conducted to determine the importance or electivity of the various invertebrates to the diets of trout at Summit Lake. No fairy shrimp (Branchiopoda), leeches (Hirudinae), or snails (Gastropoda) were observed in any of the samples collected or during the field study.

Physical and Chemical Limnology

Measurements of water temperature, dissolved oxygen, conductivity, and pH collected by depth were similar between lake areas (Table 13). Dissolved oxygen and ph were similar throughout the water column. The alkalinity, was 44 mg/L as $CaCO_3$, water hardness was 71 mg/L as $CaCO_3$, and magnesium was 27 mg/l based on the difference between total alkalinity and hardness. All three of these estimates were based on the averaged results from 2 sample titrations.

Water temperatures indicated brief stratification with differences up to 4°C at 3 and 18 foot depths (Figure 10).

DISCUSSION

In 1999, rainbow trout research was conducted in the Gulkana River drainage and at Summit Lake that flows into the Tebay River drainage.

GULKANA RIVER

From 1991 to 1998 sport fish management actions for the Gulkana River were designed to reduce the harvests of rainbow trout and steelhead, to conserve stocks, and to allow undisturbed spawning. Research efforts started in 1998 have started to define elements of Gulkana River rainbow trout history. Tag recoveries support the idea of spawning area fidelity within the Middle Fork (Stark 1999) and to the wide-ranging nature of rainbow trout. Moreover, recovery

Table 13.-Temperature (°C), dissolved oxygen (mg/l), conductivity (μS), and pH corresponding to the eastern-central and western-enter basins of Summit Lake, by depth June 29 and June 30, 1999.

June 29, 1999					June 30, 1999				
Depth (m)	Temp	D.O.	Conduct	pH	Depth (m)	Temp	D.O.	Conduct	pH
0	9.2	10.5	33.1	7.8	0	10.6	11.1	33.1	7.4
1	9.1	10.2	33.0	7.8	1	10.5	10.2	33.1	7.7
2	9	10.2	33.1	7.9	2	10.4	10.1	33.1	7.8
3	8.9	10.2	33.1	7.9	3	10.4	10.1	32.9	7.8
4	8.7	10.3	32.9	7.9	4	10.3	10.1	33.0	7.9
5	8.5	10.3	33.1	7.9	5	10.1	10.0	33.0	7.9
6	8.4	10.3	33.1	7.9	6	9.7	10.1	33.0	7.9
7	8.3	10.3	33.0	7.9	7	9.4	10.2	32.9	7.9
8	7.9	10.3	33.0	7.9	8	9.3	10.2	33.1	8.0
9	7.9	10.4	32.9	7.9	9	9.1	10.2	33.1	8.0
10	7.9	10.4	32.9	7.9	10	8.9	10.2	32.9	8.0
11	7.8	10.4	32.9	7.9	11	8.7	10.3	32.8	8.0
12	7.7	10.4	32.8	7.9	12	8.2	10.4	33.1	8.0
13	7.5	10.4	33.0	7.9	13	8.1	10.4	32.9	8.0
14	7.4	10.5	33.0	7.9	14	7.7	10.5	32.8	8.0
15	7.3	10.5	33.0	7.9	15	7.4	10.5	33.0	7.9
16	Nd	nd	nd	nd	16	nd	nd	nd	nd
17.3	7.3	2.1	59.8	7.6	17.8	7.2	5.5	35.5	7.5

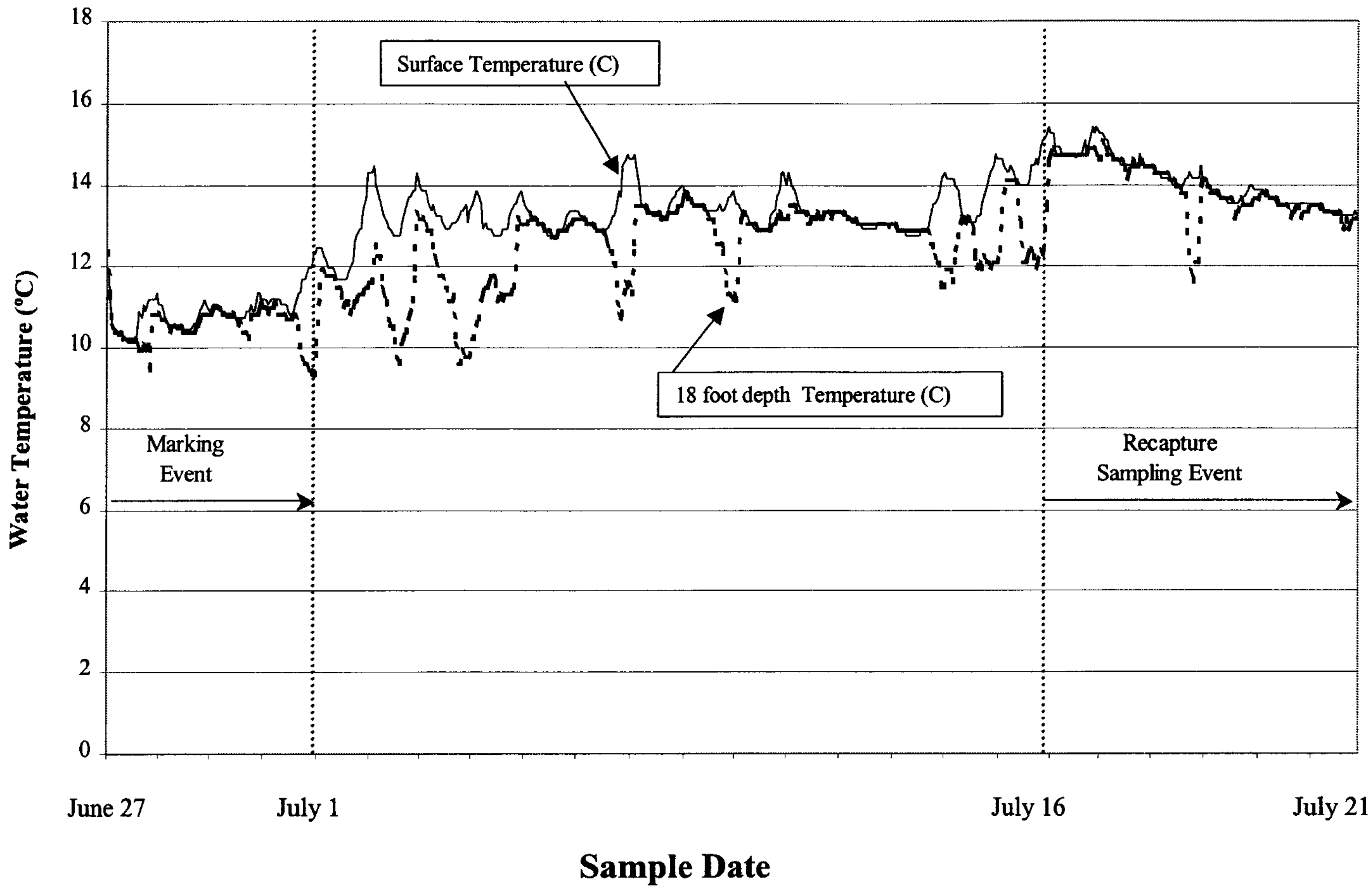

Figure 10.- Water temperatures collected at Summit Lake using submerged temperature data loggers deployed at 3 ft (surface) and 18 ft depths between June 27 and July 21, 1999

information attests to the high value of these fish to anglers since large trout can be captured more than once.

The 1999 sampling trips to the Dickey Lake and Hungry Hollow spawning areas were earlier than in 1998. At the Dickey Lake site we encountered greater numbers of spawning rainbow and steelhead trout than in 1998. At Hungry Hollow Creek, however, we encountered fewer fish than in 1998, except in upstream spawning areas. The later than normal spring breakup in 1999 allowed us to observe upstream movements of prespawning trout and steelhead into the area and the onset of spawning activity. On June 1, 1999 we counted 45 fish in active spawning concentrations. These counts, however, are not estimates of spawner abundance. Visual counts are biased towards large spawning rainbows and steelhead. During 1998 and 1999, hook and line sampling revealed that the less obvious smaller trout located in positions adjacent to the spawning pair or group may not be seen. Furthermore, not enough is known about how the spawning numbers on a particular date relate to the true numbers of spawners in a given year. Unlike spawning salmon, trout leave the spawning areas following spawning, and may not be available on the spawning grounds for bank or aerial counting. Although it is known that spawning may occur over two or more weeks in the Gulkana, a weir study at lower Talarik Creek (Russell 1977) observed that the entry to and exit from spawning areas ranged from two to 52 days.

Attempts to conduct aerial surveys to locate spawning areas and to count rainbow and steelhead were thwarted in 1999. A later spring breakup than normal resulted in high water and muddy conditions in all but one location in the West Fork of the Gulkana. The West Fork surveys were discontinued and the study objective was not met. In the future if aerial counts are needed in the typically clear Middle Fork Gulkana, a larger and more powerful helicopter should be used to overcome some of the problems encountered in this study. Counting spawners from helicopters or the stream banks should coincide with significant levels of spawning activity. During spawning, the trout concentrated in shallow open areas, and were easy to spot, and were quite oblivious to disturbances. Aerial counts may be better if scheduling would allow the taking advantage of peak spawning activity. It is likely that past helicopter counts conducted during 1984 (Williams and Potterville 1985) coincided with greater levels of spawning activity.

Future research on rainbow trout of the Gulkana River should be directed to improve the knowledge on life history and seasonal range of resident rainbow trout so that stock monitoring tools may be developed. Some of this information may be gathered using radiotelemetry.

SUMMIT LAKE

In 1999, we responded to anglers and nearby lodge owner concerns over the health of the rainbow trout population by conducting a comprehensive stock assessment to obtain information for possibly redirecting the management of this trout population. There was concern over the small sizes and skinny condition of fish, which suggested that the trout population was stunted in this special management area. We planned and conducted the mark-recapture study with timing similar to past stock monitoring trips. This allowed the most relevant comparisons with past data, allowed characterization of the spawning concentrations, and allowed an examination of the sizes of trout available to anglers during the fishing season.

During the study, gillnetting killed an unacceptable number of fish, and was discontinued for the marking event. This was problematic, since gillnetting and angling were the only gear types that were efficient in capturing fish away from the shoreline and in deep areas. Seining was discontinued in the second sampling event in favor of using additional fyke traps. Fyke traps were an extremely effective gear that allowed sampling around the perimeter of the lake, ~24 hrs per day fishing effort, and yielded high catches of rainbow trout. Fyke traps caught all sizes of fish, including the largest sampled fish (455 mm FL). These traps intercepted and captured tagged trout moving to and from the spawning areas, and also captured immature fish that did not spawn in 1999.

The estimate of abundance was 13,767 trout ≥ 130 mm FL (~ 5 in) which was considered a minimum estimate. Gillnet captured fish from offshore areas, which were found to have a low tagging density, were not used to help generate the estimate of abundance. This low tagging density may be related to the behavior of fish in offshore areas which offshore remain and do not mix with fyke areas (inshore) between events. In future assessments, a greater number of fish in offshore areas should be marked to examine this bias. Since marked fish near shore had a higher catch rate, another gear-type might allow equalization of sampling effort. One possibility might include hoop traps that could be suspended at varied depths between the surface and bottom. The basis of the bias might also be examined by knowing the movement behavior of fish relative to the near-shore fyke sets. A sample of fish captured in near shore and offshore areas could be implanted with ultrasonic transmitters and tracked to determine the amount of mixing.

This study indicated that the rainbow trout population of Summit Lake and Bridge Creek was dense and composed of small fish. None of the sampled trout were large enough for legal harvest in 1999[7] under the minimum size regulation of 32 in (810 mm FL). The largest trout sampled was 455 mm FL or 18 inches, and only 27% were greater than 12 in (≥ 290 mm FL). A shift in the length composition of the samples from this study compared to past studies was apparent (Figures 8 and 9).

The 1999 age composition indicated a strong age-2 component in the population (~36%). We observed the onset of spawning behavior in trout as small as 120 mm FL. Immature fish however, were found in all sampled sizes. This suggested a non-sigmoidal pattern of maturity or recruitment to the spawning population. This is unlike some other species such as Arctic grayling (Clark 1992). Furthermore, individual year classes may gradually recruit to the spawning population, similar to some pacific salmon. Even though this phenomenon may be related to density, this pattern should be considered when structuring regulations based on size since either early- or late-maturing fish may be subjected to differential exploitation. In future assessments, it may be valuable to collect age samples during the spawning period.

Declines in the average length at age were apparent when current data were compared to past data (Figure 7). Unfortunately, no abundance estimates are available prior to this study, which could document a change in population size. One form of abundance indexing requires the assumption that the spawning population represents the overall population. Visual counts of trout in spawning areas taken from field notes and trip reports indicated sequential increases in

---

[7] In the December 1999 meeting of the Alaska Board of Fish, proposed regulations to re-allow harvest of smaller fish were supported. The resulting regulations allow anglers to harvest 10 trout with a maximum size limit of 12 inches, from July 1 to May 31.

the total number of trout and a concurrent decline in the number of larger trout (ADF&G *Unpublished*):

Date	Number of Spawners observed on one day	Notes
6/27/84	~200 fish	Large fish not mentioned; all fish sampled were ≥ 20 in
6/26/86	~400 fish	~40% were over 25 in
1988	566 fish average (471 to 668)	10 to 15% were large trout
6/22/90 6/28/90	800 fish (6/22/90) 600 fish (6/28/90)	"saw 3 between 20 and 22 in; most were 10-17" "fish ranging in the high teens",
6/28/99	2,000	None

This information, suggests a pattern of change in the population that has resulted in the current condition of the population. It may never be known whether the replacement of large and trophy size trout with smaller maturing trout is attributed to:

- angling exploitation (directed harvests, or hooking injuries);
- a unique pattern of natural attrition, which allowed increased spawning success of early maturing trout;
- detrimental changes or stresses to the food web at Summit Lake; or,
- a combination of these and other factors.

The population density of Summit Lake is believed to be high relative to past unreported densities. Stunting is suspected based on the changes in the sampled length composition and declining individual growth as seen in a change in the length at age. When patterns such as this exist, smaller fish may be replacing larger fish or a decline in food may have occurred. This may have occurred through a top-down control or effect on invertebrate prey abundance (Koenings and Kyle 1997; Wang et al. 1996; Amundsen 1999; Elser et al. 1995; Mueller and Rockett 1980) and result in increasing levels of competition for remaining food resources. Such effects on the forage base can be reversed to increase the relative zooplankton availability by either enhancing primary and secondary production or the reduction of predator density.

Augmenting natural production of invertebrate prey to increase fish growth can be accomplished by lake fertilization (Johnston et al. 1999; Koenings and Kyle 1997). This approach is expensive and used when costs are offset by large scale returns of commercially valuable species such as sockeye salmon. Otherwise, reducing fish density and intra-specific competition for food may be the best alternative to increase individual growth of fish with a goal of improving sport fishing quality for larger fish. This can occur through reductions in stocking densities (Naito 1992) or through population thinning in naturally reproducing populations (Donald and Alger 1989; Amundsen et al.1993; Klemetsen et al. 1992; Langeland 1986). In Lake Takvatn located in Norway, introduced Arctic char *Salvelinus alpinus* became exceptionally numerous, but stunted in size, and brown trout *Salmo trutta* populations failed to thrive (Klemetsen et al. 1992). A large-scale thinning project was undertaken. A five-year program of mass removals thinned the char population and restored lost growth to remaining char and reintroduced brown trout.

Limnological sampling indicated a relatively high-density zooplankton population composed of four species common in other Alaskan lakes that support salmon and trout production. The level of primary production (phytoplankton) that was observed may be low relative to seasonal mean values at other Alaskan lakes. This probably reflects the timing of the study. We sampled in the middle of July at a time after seasonal phytoplankton blooms, and at a time when zooplankton density may have been near the peak. It is likely that our sampled concentrations of chlorophyll-a reflected cropping by the zooplankton. The zooplankton population we sampled was dominated by a Cladoceran, *Daphnia longiremis,* which measured 1.2 mm in size. Other researchers (Beauchamp 1990; Wang et al. 1996; Mueller and Rockett 1980) related *Daphnia* sp. as an important forage component for rainbow trout from 250 to 500 mm. When given the choice, trout preferred *Daphnia pulex* > 1.5 mm over smaller *D. pulex*. If smaller rainbow trout prefer Daphnia that are 1.2 mm or less, then it is possible that smaller trout in Summit Lake may have exploited or cropped the zooplankton population, resulting in few or larger Daphnia. Larger trout at Summit Lake may compete for other invertebrates such as amphipods, or cannibalize smaller trout in the absence of large Daphnia.

We observed two released trout < 100 mm eaten by larger trout. The role of cannibalism, however, for trout in Summit Lake is not known. Other studies on rainbow trout (Beauchamp 1990), brown trout *Salmo trutta* (L'Abee-Lund et al. 1992), and Arctic char (Hobson and Welch 1995; Riget et al. 1986) indicated piscivory occurs after fish attain threshold sizes relative to prey size. If these predator-to-prey size ratios were applied to the Summit Lake rainbow population, Brown trout 3:1 ratio and Arctic char 4:1, then rainbow trout would need to be 402 to 536 mm FL before preying upon age-1 trout (mean length 134 mm FL). The 1999 estimated abundance and size composition estimates indicate that approximately 62 of the 13,767 trout sampled (0.4%) were 400 mm or larger. Hence, if these relationships hold then cannibalism on fish may not be important in the current population. In the absence of cannibalism there may be greater competition for the existing food resources.

In lake manipulation experiments with rainbow trout (Landry et al. 1999) smaller trout sought marginal areas to avoid predation when in the presence of larger trout, and spread throughout the lake when larger trout were absent. Our fyke traps captured all sampled sizes of trout in near shore areas, but we did not obtain information concerning the presence or absence of small fish in deeper areas. Donald and Alger (1986) reported that in populations of stunted lake trout *Salvelinus namaycush,* maturity occurs at an earlier age and mortality rates are greater. Greater mortality rates effectively lower predation risks and allows smaller lake trout to enter productive pelagic feeding areas. Age-1 and older trout at Summit Lake may behave in a similar fashion under the lower risk of predation, and may more freely exploit the zooplankton resource in the off shore area thereby contributing to the stunted condition.

If the poor growth is related to density effects, as with other stunted populations, thinning may be the best approach to rehabilitate this fishery. Angling exploitation in the middle 1980s may have triggered the population change, however it is unlikely that a similar number of anglers could reverse those effects. Caution must be observed, however, because the results of thinning can be short lived (Langland 1986; Donald and Alger 1989). Significant efforts must be taken similar to those at Lake Takvatn, to cause significant changes in the trophic dynamics of a stunted population. In several studies insufficient exploitation on brook trout *Salvelinus fontinalis* and Arctic char increased growth, but recruitment also increased (Langeland 1986; Donald and Alger 1989).

Removal of fish from a population to allow increased growth may necessarily require exceeding maximum sustainable yield (MSY). In order to successfully increase the growth of trout, thinning pressure would need to be strong enough to override compensatory changes in recruitment from the increasing availability of food. Similar to Takvatn, a program of sequential removal could achieve the necessary pressure if conducted over enough years to substantially reduce recruitment levels. Donald and Alger (1989) suggested blocking access to spawning areas to reduce population density of brook trout through year-class failures in one or more years. For Summit Lake this approach would be very difficult, but removal could target spawning fish. Additional removals of pre-spawning fish would also impact spawning of future year classes.

Small spawning males have been documented in other trophy rainbow fisheries in Alaska (Russell 1977). However, we observed spawning and non-spawning fish from all sampled sizes. Moreover, many of the largest fish sampled were sexually immature fish, which we documented through dissections. A finding of delayed maturity was previously noted at Summit Lake. Large immature trout (> 700 mm) were captured away from the spawning area during the time of spawning (Williams and Potterville 1985). In some cases the presence of early and late maturing rainbow trout has a latent genetic basis that has been exploited through selective breeding programs in New Zealand to increase tendencies toward late maturation and larger-sized rainbow trout (T. Northcote, Summerland, British Columbia, personal communication). At Lake Tarawera, New Zealand, this approach was used to maintain the presence of exceptionally large rainbow trout in the sport fishery and spawning gene pool (P. Mylechreest, Revelstoke, British Columbia, personal communication).

Other populations of large late maturing rainbow trout also capitalize on competition at spawning areas to retain their life history pattern. It is believed that the Gerrard strain of rainbow trout are maintained because large size allows construction of spawning redds in a very limited spawning area composed of coarse spawning rubble, while the smaller fish cannot (Dr. Thomas Northcote, Ibid.). Another strain, the presently disappearing yellowfin rainbow trout strain also uses competitive advantages of large size in extensive migrations to maintain their life history (K. Bray, B.C. Environment, Revelstoke B.C., personal communication). At Summit Lake, it is possible that the removal of large trout in the middle 1980s allowed smaller, early-maturing trout to increase their spawning success and tendency for this life-history pattern in the population.

It may be possible at Summit Lake to capture and out-stock early maturing spawners and smaller trout to other locations. This may improve growth and average size of rainbow trout at Summit Lake. In this manner, a series of sequential removal of early maturing and small fish at the onset of the spawning period could reduce the density of fish and may improve growth rates.

ACKNOWLEDGMENTS

The author thanks Tom Taube, Wolf Cartusciello, and Chris Stark for help with field work on the Gulkana River project. Thanks are also extended to Charlie Swanton, Tim Viavant, Jim Fish, Tony Roof, Cal Skaugstad, Tom Taube, Don Roach, Becky Kelleyhouse, Dave Sarafin, and Jason Dye for help on the Summit Lake project. Thanks also go to Al Lee for his piloting and historical perspectives. Phyllis Weber-Scannell is thanked for help on limnological studies and for laboratory assistance. Chris Stark of the Marine Sciences Department at the University of Alaska is especially thanked for his generous assistance and expertise with zooplankton sampling and analysis. Special thanks go to Thomas Northcote, Peter Mylechreest, and Karen Bray from BC Environment for exposing me to their works on trophy sized rainbow trout in Canada and New Zealand. Many additional people are also thanked including Dave Rutz, Ken Roberson, Fred Williams, Nicky Szarzi, Chris Stark, Tom Capiello, Matt Williams, Howard Knutson, and Bob Huffman for fruitful conversations on their involvements with steelhead and rainbow trout in the Copper Basin. Carl Mitchell and Devie Sharp of the Wrangell-St. Elias National Park are thanked for their support and cooperation with work at Summit Lake. Mike Wallendorf is thanked for statistical support. Mac Minard and Peggy Merritt are thanked for administrative support. Thanks also go to Sara Case for final preparation of the report. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-14, Job No. 3-5.

LITERATURE CITED

ADF&G (Alaska Department of Fish and Game) *Unpublished a.* Lake and stream survey files. Located at Alaska Department of Fish and Game, Glennallen.

ADF&G (Alaska Department of Fish and Game) *Unpublished b.* Statewide harvest survey data. Located at Alaska Department of Fish and Game, Anchorage.

ADF&G (Alaska Department of Fish and Game). 1998. Atlas to the catalog of waters important for spawning, rearing and migrating anadromous fishes; South Central Regional Resource: Management Region II, as revised APHA Nov 4, 1998. Habitat Division, Juneau.

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

Allin, R. W. 1957. Catch distribution, composition, and size structure, sport fishing, Anchorage Area. U.S. Fish and Wildlife Service and Alaska Game Commission, Federal Aid in Fish Restoration, Quarterly Progress Report, March 30, 1957, Project F-1-R-6, Job 2-A, Juneau.

Alvord, W. 1954. Validity of age determinations from scales of brown trout, rainbow trout, and brook trout. Transactions of the American Fisheries Society 83:91-103.

Amundsen, P. A., A.. Klemetsen, and P. E. Grotnes. 1993. Rehabilitation of a stunted population of Arctic char by intensive fishing. North American Journal of Fisheries Management 13:483-491.

Amundsen, P. A. 1999. Changes in food consumption of Arctic charr during the stock depletion experiment in Takvatn. Pages 9-11 *in* F. W. Kircheis *editor.* Proceedings of the Eighth and Ninth International Charr Workshops on Arctic Charr. Institute of Freshwater Research, S-178:93 Drottningholm, Sweden.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1997. Revision to rapid bioassessment protocols for use in streams and rivers: periphyton, benthic, macroinvertebrates, and fish. U.S. Environmental Protection Agency. EPA 841-D-97-002.

LITERATURE CITED (Continued)

Beamish, R. J. and G. E. McFarlane. 1987. Current trends in age determination methodology. Pages 15-42 *in* Age and Growth of fish. Iowa State University Press, Ames, Iowa.

Beauchamp, D. A. 1990. Seasonal and diel food habits of rainbow trout stocked as juveniles in Lake Washington. Transactions of the American Fisheries Society 119:475-482.

Bradley, T. J. 1991. Cook Inlet rainbow trout studies 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-54, Anchorage, Alaska.

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.

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.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1: 131-160.

Clark, R. A. 1992. Age and size at maturity of Arctic grayling in selected waters of the Tanana drainage. Alaska Department of Fish and Game, Fishery Manuscript Number 92-5, Anchorage.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Donald, D. B. and D. J. Alger. 1986. Stunted lake trout *Salvelinus namaycush* from the Rocky Mountains. Canadian Journal of Fisheries and Aquatic Sciences 43:608-612.

Donald, D. B. and D. J. Alger. 1989. Evaluation of exploitation as a means of improving growth in a stunted population of brook trout. North American Journal of Fisheries Management 9:177-183.

Dunaway, D. O. 1993. Status of rainbow trout stocks in the Agulowak and Agulupak Rivers of Alaska during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-41, Anchorage.

Elser, J. J., C. Luecke, M. T. Brett, and C. R. Goldman. 1995. Effects of food web compensation after manipulation of rainbow trout in an oligotrophic lake. Ecology 76: 52-69.

Everhart, W. H. and W. D. Youngs. 1981. Principles of Fishery Science. Cornell University Press. Ithaca, New York

Ferguson, R. A. and B. L. Tufts. 1992. Physiological effects of brief air exposure in exhaustively exercised rainbow trout *Oncorhynchus mykiss*: implications for "catch and release" fisheries. Canadian Journal of Fisheries and Aquatic Sciences 49:1157-1162.

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.

Fleming, D. F. 1999. Surveys and stock monitoring of rainbow trout and steelhead in the upper Copper River drainage during 1998. Alaska Department of Fish and Game, Fishery Data Series Number 99-37, Anchorage.

Goodman, L. A. 1960. On the exact variance of a product. Journal of the American Statistical Association, Vol 55:708-713.

Hobson, K. A. and H. E. Welch. 1994. Cannibalism and trophic structure in a high Arctic lake: insights from stable-isotope analysis. Canadian Journal of Fisheries and Aquatic Sciences 52:1195-1201.

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

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

LITERATURE CITED (Continued)

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1997. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series Number 97-29, Anchorage.

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1998. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series Number 98-25, Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, Gail Heineman, and A. E. Bingham. 1999. In prep. Harvest and catch in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Johnson, R. E. 1996. Situk River steelhead trout studies, 1994. Alaska Department of Fish and Game, Fishery Data Series Number 96-1, Anchorage.

Johnston, N. T., M. D. Stamford, K. I. Ashley, and K. Tsumura. 1999. Response of rainbow trout *Oncorhynchus mykiss* and their prey to inorganic fertilization of an oligotrophic montane lake. Canadian Journal of Fisheries and Aquatic Sciences 56:1011-1025.

Jones, D. E. *Unpublished.* Handbook for interpretation of steelhead trout scales in southeast Alaska. Alaska Department of Fish and Game, Division of Sport Fish, Juneau.

Klemetsen, A. , P. Grotnes, P. A. Amundsen, M. A. Svenning, R. Kristoffersen, G. A. P. Dahl-Hansen, and R. Knudsen. 1992. The emergence of ferox trout *Salmo trutta* in Takvatn, North Norway: an ecological result of the mass removal of Arctic char *Salvelinus alpinus.* Proceedings of the Seventh ISACF Workshop on Arctic Charr, 1992. Institute of Freshwater Research, Drottingholm.

Koenings, J. P., G. B. Kyle, J. A. Edmundson, and J. M. Edmundson. 1987. Limnological field and laboratory manual: methods for assessing aquatic production. Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development. Report Number 71, Juneau.

Koenings, J. P. and G. B. Kyle. 1997. Consequences to juvenile sockeye salmon and the zooplankton community resulting from intense predation. Alaska Fishery Research Bulletin 4(2):120-135

Landry, F., J. R. Post, and E. A. Parkinson. 1999. Spatial ontogeny of lentic age-0 rainbow trout, *Oncorhynchus mykiss*: whole-lake manipulations of population size structure. Canadian Journals of Fisheries and Aquatic Science 56: 1916-1928.

Langeland, A. 1986. Heavy exploitation of a dense resident population of Arctic Char in a mountain lake in central Norway. North American Journal of Fisheries Management 6:519-525.

LaFlamme, T. R. 1997. Creel and escapement estimates for chinook salmon on the Gulkana River, 1996. Alaska Department of Fish and Game, Fishery Data Series Number 97-12, Anchorage.

L'Abee-Lund, J. H., A. Langeland, and H. Sægrov. 1992. Piscivory by brown trout *Salmo trutta* L. and Arctic charr *Salvelinus alpinus* L. in Norwegian lakes. Journal of Fish Biology. 41:91-101.

Maher, F. P. and P. A. Larkin. 1955. Life history of the steelhead trout of the Chilliwack River British Columbia. Transactions of the American Fisheries Society 84:27-38.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-I-A).

Mills, M. J. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A).

Mills, M. J. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

Mills, M. J. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A).

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A).

Mills, M. J. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A).

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A).

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2).

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Minard, R. E. and J. E. Dye. 1998. Rainbow trout sampling and aging protocol. Alaska Department of Fish and Game, Fishery Data Series No. 98-2, Anchorage.

Mueller, J. W. and L.C. Rockett. 1980. Lake De Smet, history and management. Wyoming Game and Fish Department, Fishery Research Report No. 3, Cheyenne.

Naito, G. J. 1992. Modeling the dynamics of fish and anglers for management of rainbow trout (Oncorynchus Mykiss) trophy lakes in British Columbia. M.S. Thesis. Simon Fraser University. Report No. 105.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada. Bulletin 191.

Riget, F. F., K. H. Nygaard, and B. Christensen. 1986. Population structure, ecological segregation, and reproduction in a population of Arctic char *Salvelinus alpinus* from Lake Tasersuaq, Greenland. Canadian Journal of Fisheries and Aquatic Science 43: 985-992.

Roberson, K. 1986. Copper River report on individual chinook and sockeye salmon spawning population potential for use as brood stocks. Alaska Department of Fish and Game, Prince William Sound Data Report 1986-8, Anchorage, Alaska.

Rutz, D. S. 1992. Age and size statistics for rainbow trout collected in the Susitna River drainage during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-26, Anchorage, Alaska.

LITERATURE CITED (Continued)

Russell, R. 1977. Rainbow trout life history studies in lower Talarik Creek-Kvichak drainage. Federal Aid in Fish Restoration, Annual Report of Progress, 1976-1977, Project F-9-9 (G-II-E), Juneau.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffin and Company, Limited, London.

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

Szarzi, N. J. 1996. Area Management report for the recreational fisheries of the Upper Copper/ Upper Susitna Management Area, 1995. Alaska Department of Fish and Game, Fishery Management Report No. 96-5, Anchorage.

Taube, T. T., K. G. Wuttig, and L. Stuby. 1998. Lake Trout studies in the AYK Region, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-24, Anchorage, Alaska.

Wang, L., K. Zimmer, P. Diedrich, and S. Williams. 1996. The two-story rainbow trout fishery and its effect on the zooplankton community in a Minnesota Lake. Journal of Freshwater Ecology 11:67-80.

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. 1984. 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, 1983-1984, Project F-9-16, 25 (G-I-F), 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.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc. Englewood Cliffs, N. J. 718 pp.

Appendix A

Appendix A1.- Methodologies to compensate for bias due to unequal catchability by length.

Case	Result of First K-S Test[a]	Result of second K-S test[b]	Inferred Cause
I[c]	Fail to reject H_o	Fail to reject H_o	There is no size-selectivity during either sampling event.
II[d]	Fail to reject H_o	Reject H_o	There is no size-selectivity during the second sampling event, but there is during the first sampling event.
III[e]	Reject H_o	Fail to reject H_o	There is size-selectivity during both sampling events.
IV[f]	Reject H_o	Reject H_o	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 events 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. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix B

Appendix B1.-Mean length at age estimates, standard errors, and sample sizes for rainbow trout sampled at Summit Lake during stock monitoring and stock assessment projects conducted in 1983-1984 (Williams and Potterville 1984, 1985), 1988, 1990, 1991, 1994, and 1999.

1983-4			
Age	Length	SE	sample
1	98	4	5
2	208	41	3
3			
4			
5	535	25	10
6	669	14	24
7	741	24	4
8			
9			
Total			46

1988			
Age	Length	SE	sample
1			
2	228	12	3
3	287	7	29
4	379	8	37
5	515	20	14
6	597	14	10
7	692	93	2
8	710		1
9	806	54	2
Total			98

1990			
Age	Length	SE	sample
1			
2	298	37	10
3	186	10	12
4	221	6	64
5	336	8	40
6	456	5	95
7	511	7	77
8	618	13	4
9	637		1
Total			303

1991			
Age	Length	SE	sample
1			
2	160		1
3	264	38	20
4	387	75	17
5	433	40	13
6	443	11	2
7			
8			
9			
Total			53

1994			
Age	Length	SE	sample
1			
2	145	4	3
3	197	42	16
4	240	53	71
5	301	59	26
6	333	45	9
7			
8			
9			
Total			125

1999			
Age	Length	SE	sample
1	134	2	62
2	161	1	385
3	209	2	128
4	278	4	82
5	307	2	153
6	319	4	58
7	330	21	7
8	325	16	2
9			
Total			877

Appendix C
Data File Listing

Appendix C1.-Data file listing

Data File	Description
1999 Gulkana Rbt	1999 field data from the Middle Fork Gulkana
i-031601b011999	1999 Summit Lake marking event data file
i-031602b011999	1999 Summit Lake recapture event data file

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