Fishery Data Series No. 98-39

Stock Status of Chena River Arctic Grayling in 1997, and Radiotelemetry Studies, 1997-1998

by

William P. Ridder

December 1998

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

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

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by

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ABSTRACT

Stock status of Arctic grayling *Thymallus arcticus* in the lower 152 km of the Chena River was described by population abundance, age and length composition, recruitment, and survival rate estimates during July 1997. Parameter estimates were influenced by low capture probabilities brought on by extreme water conditions during the sampling (record low discharge and high temperatures). Abundance estimates for the defined stock (≥150 mm FL) could not be made due to the exclusion of small fish in parameter estimates for the upper study section. However, estimates of the population of large fish (≥270 mm FL) was 11,502 Arctic grayling (SE = 1,729). Stock-size Arctic grayling (150 - 269 mm FL) represented 66 % of all captured fish ≥ 150 mm FL. Annual recruitment of age-5 fish between 1996 and 1997 was 3,774 Arctic grayling (SE = 560) and annual survival during this period was 51.3% (SE = 6.3%).

Estimated abundance of 1992 brood year (age-5) hatchery-reared Arctic grayling, released in 1993, was 388 fish (SE = 87). Survival of age-5 hatchery-reared Arctic grayling from July of 1996 to July of 1997 was 47.6 % (SE = 3.5%). Estimated abundance of 1993 brood year (age-4) hatchery-reared Arctic grayling, released in 1994, was 173 fish (SE = 48). Survival of age-4 hatchery-reared Arctic grayling from July of 1996 to July of 1997 was 30.2% (SE = 3.3%). From 1992 through 1994, a total of 126,371 age-1 and 23,199 age-0 Arctic grayling have been released into the Chena River. Estimated abundance of all releases of Arctic grayling in 1997 was 561 fish (SE = 99). Though low initial post-release survival (~60% during the first month) and low overwinter survival (~8% per year) is indicated for the failure of the releases, rapid post-release emigration may have influenced these parameter estimates. Sampling to detect emigration was not conducted.

Radio telemetry of 54 Arctic grayling inhabiting four forks of the Chena River and the mainstem river upstream of river kilometer 144 in August was used to estimate the proportion that later entered the lower 144 km of the mainstem. Eight aerial surveys were conducted between September 1997 and July 1998. Of fish alive eight months after tagging, 34% (SE = 9%) had overwintered and 37% (SE = 9%) spawned below river kilometer 144. Fish overwintered and spawned as low as river kilometer 35 of the mainstem and in all four forks and two tributaries. The percentage of fish present in the lower 144 km during open water ranged from 0% at tagging in mid-August to 13% in September, 35% in late April, 29% in May, 8% in June, and 0% in July. Accurate estimates of the duration of residence in the lower river could not be determined due to failure of remote sensing to detect radio tags. On 28 July, 60% of tagged fish were within 5 km of release sites.

Key words: Arctic grayling, *Thymallus arcticus*, electrofishing, population abundance, composition, Relative Stock Density, recruitment, survival rate, overwintering, spawning, radiotelemetry, Chena River.

CHAPTER I: STOCK ASSESSMENT

INTRODUCTION

BACKGROUND

The Chena River is a clear water tributary to the Tanana River originating in the Tanana Uplands 144 km east of Fairbanks. It flows approximately 252 km from its uppermost reach in the East (Middle) Fork to its confluence with the Tanana River at Fairbanks. The river drains a watershed of 5,130 km^2 and includes five major tributaries: North Fork, West Fork, South Fork, East (Middle) Fork, and the Little Chena River (Figure 1). Collectively, these major tributaries and the mainstem are over 470 km in length. Urban development along the river is extensive along the lower 40 km of the river, and road accessibility extends along a majority of the lower 183 km.

The Chena River provides habitat for 14 fish species: Arctic grayling *Thymallus arcticus*, chinook salmon *Oncorhynchus tshawytscha*, chum salmon O. *keta*, round whitefish *Prosopium cylindraceum*, slimy sculpin *Cottus cognatus*, burbot *Lota lota*, longnose sucker *Catostomus*

2

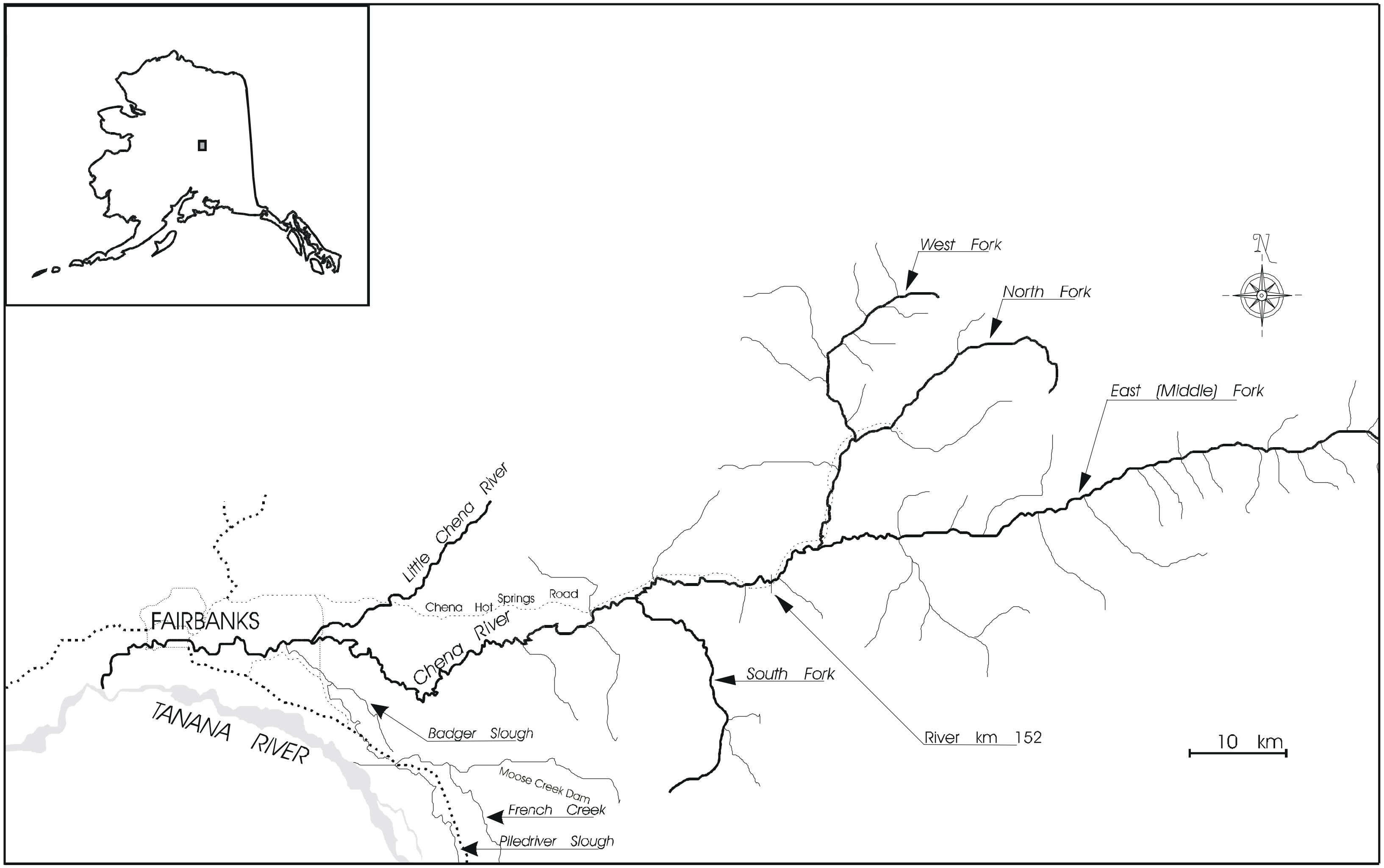

Figure 1.-The Chena River drainage.

catostomus, Arctic lamprey *Lampetra japonica*, northern pike *Esox lucius*, sheefish *Stenodus leucichthys*, humpback whitefish *Coregonus pidschian*, broad whitefish *C. nasus*, least cisco *C. sardinella* and lake chub *Couesius plumbeus*. The latter six species are more likely found in the lower half of the river while the former eight species may be found throughout the river. Recreational fisheries are conducted on nine of the 14 species (in parenthesis is total catch in 1996 from Howe et al. 1997): Arctic grayling (50,083), salmon sp. (4,387), northern pike (3,558), burbot (540), and whitefish sp. (209). By regulation, salmon fishing is closed above the Moose Creek Dam at river kilometer 72.

Due to its proximity to Fairbanks and road accessibility, the Chena River supports the largest Arctic grayling fishery in North America. However, the status and character of the fishery has changed dramatically since 1985. From 1977 through 1984, annual harvests averaged 30,000 Arctic grayling and annual angling effort for all species averaged 34,000 angler days (Mills 1979-1985, Table 1, Figure 2). Since 1985, harvests declined dramatically to an average of 4,400 Arctic grayling while effort decreased to 27,900 angler days (Mills 1986-1994, Howe et al. 1995-1996, Table 1, Figure 2). Concomitant with the rapid decline in harvest was a decline in Arctic grayling population abundance. Stock assessment projects during 1986 (Clark and Ridder 1987b) and 1987 (Clark and Ridder 1988) documented a decline in population abundance of 49% between these two years (Appendix A1). These trends in the fishery and population prompted fishery managers to process emergency regulations for the 1987 season to reduce harvest. These emergency regulations (1 through 3) were adopted and amended (4 and 5) by the Alaska Board of Fisheries and were:

1. catch-and-release fishing from 1 April to the first Saturday in June;
2. a 12 inch (305 mm) minimum total length limit from the first Saturday in June until 31 March;
3. restriction of terminal gear to unbaited artificial lures only throughout the Chena River, and bait fishing allowed downstream of the Moose Creek Dam with hooks having a gap larger than 0.75 inch (19 mm);
4. catch-and-release fishing year around from river kilometer 140.8 downstream to river kilometer 123.2; and,
5. reduce the possession limit from 10 to 5 fish (Tanana River drainage-wide regulation).

These regulations were the first changes in Arctic grayling management since 1975, when the daily bag limit was decreased from 10 to 5 fish.

By 1990, annual evaluation of the effects of these new regulations showed little effect on population and fishery trends which prompted the Board of Fisheries to implement a daily bag limit of two fish drainage wide and single hook regulations upstream of the Moose Creek Dam. On 1 July 1991, fishery managers invoked Emergency Order authority to reduce the daily bag limit to 0 fish in the entire Chena River drainage. This Emergency Order remained in effect through 1994. In 1994, the Board of Fisheries passed a regulation to keep the daily bag limit at 0 fish through 1997. In 1997, the Board of Fisheries retained the regulations through 2000.

Since 1991 and the imposition of catch and release regulations, the trend in the population and the fishery has been upward. Estimated abundance of Arctic grayling increased from 26,756 fish in 1991 to 45,114 fish in 1995 (Appendix A1) while angling effort increased from 12,654 angler days in 1992 to 45,942 angler days in 1996 (Table 1).

Table 1.-Summary of total angling effort and Arctic grayling harvest and catch from the Chena River, 1977-1996 (taken from Mills 1979-1994 and Howe et al. 1995-1997).

	Lower Chena River[a]			Upper Chena River[b]			Entire Chena River		
Year	Angler-Days	Harvest	Catch	Angler-Days	Harvest	Catch	Angler-Days	Harvest	Catch
1977	---	---	---	---	---	---	30,003	21,723	---
1978	---	---	---	---	---	---	38,341	33,330	---
1979	9,430	11,290	---	8,016	11,664	---	17,446	22,954	---
1980	13,850	18,520	---	10,734	16,588	---	24,584	35,108	---
1981	11,763	10,814	---	10,740	13,735	---	22,503	24,549	---
1982	18,818	11,117	---	15,166	12,907	---	33,984	24,024	---
1983	17,568	7,894	---	16,725	10,835	---	34,293	18,729	---
1984	20,556	13,850	---	11,741	12,630	---	32,297	26,480	---
1985	11,169	2,923	---	8,568	3,317	---	19,737	6,240	---
1986	18,669	4,167	---	10,688	3,695	---	29,357	7,862	---
1987[d]	12,605	1,230	---	10,667	1,451	---	23,727	2,681	---
1988[d,e]	16,244	2,686	---	9,677	1,896	---	25,921	4,582	---
1989 [d,e]	20,317	7,194	---	10,014	5,441	---	30,331	12,635	---
1990 [d,e,f]	18,957	3,494	22,062	6,949	945	10,769	25,906	4,439	32,831
1991 [d,e,f,g]	12,547	2,997	14,860	8,591	722	14,688	21,138	3,719	29,548
1992[h]	7,671	0	11,270	4,983	0	9,039	12,654	0	20,309
1993[h]	15,631	0	26,805	6,018	0	17,173	21,649	0	43,978
1994[h]	18,718	33	32,759	7,912	82	27,193	26,630	115	59,952
1995[h]	23,219	0	15,181	13,319	212	23,428	36,538	212	38,609
1996[h]	30,714	0	23,278	15,228	0	26,805	45,942	0	50,083
Mean 1979-1996	16,551	5,456	20,888	10,319	5,340	18,442	26,869	10,796	39,330

-continued-

[a] Lower Chena River is from the mouth upstream to 40 km Chena Hot Springs Road (Mills 1988). For 1991 through 1996 the Lower Chena River included Badger Slough.

[b] Upper Chena River is the Chena River and tributaries accessed from the Chena Hot Springs Road beyond 40 km on the road (Mills 1988). Angling effort is for all species of fish.

[c] Angler-days and harvest are computed for the Chena River and Badger Slough.

[d] Special regulations were in effect during 1987 through 1991. These regulations were: catch-and-release fishing from 1 April until the first Saturday in June; a 305 mm (12 inch) minimum length limit; and, a restriction of terminal gear to unbaited artificial lures.

[e] In addition to the special regulations, a catch-and-release area was created on the Upper Chena River (river kilometer 140.8 to 123.2).

[f] The daily bag and possession limits were reduced from five fish to two fish in 1990.

[g] During 1991, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 July through 31 December.

[h] During 1992 through 1996, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

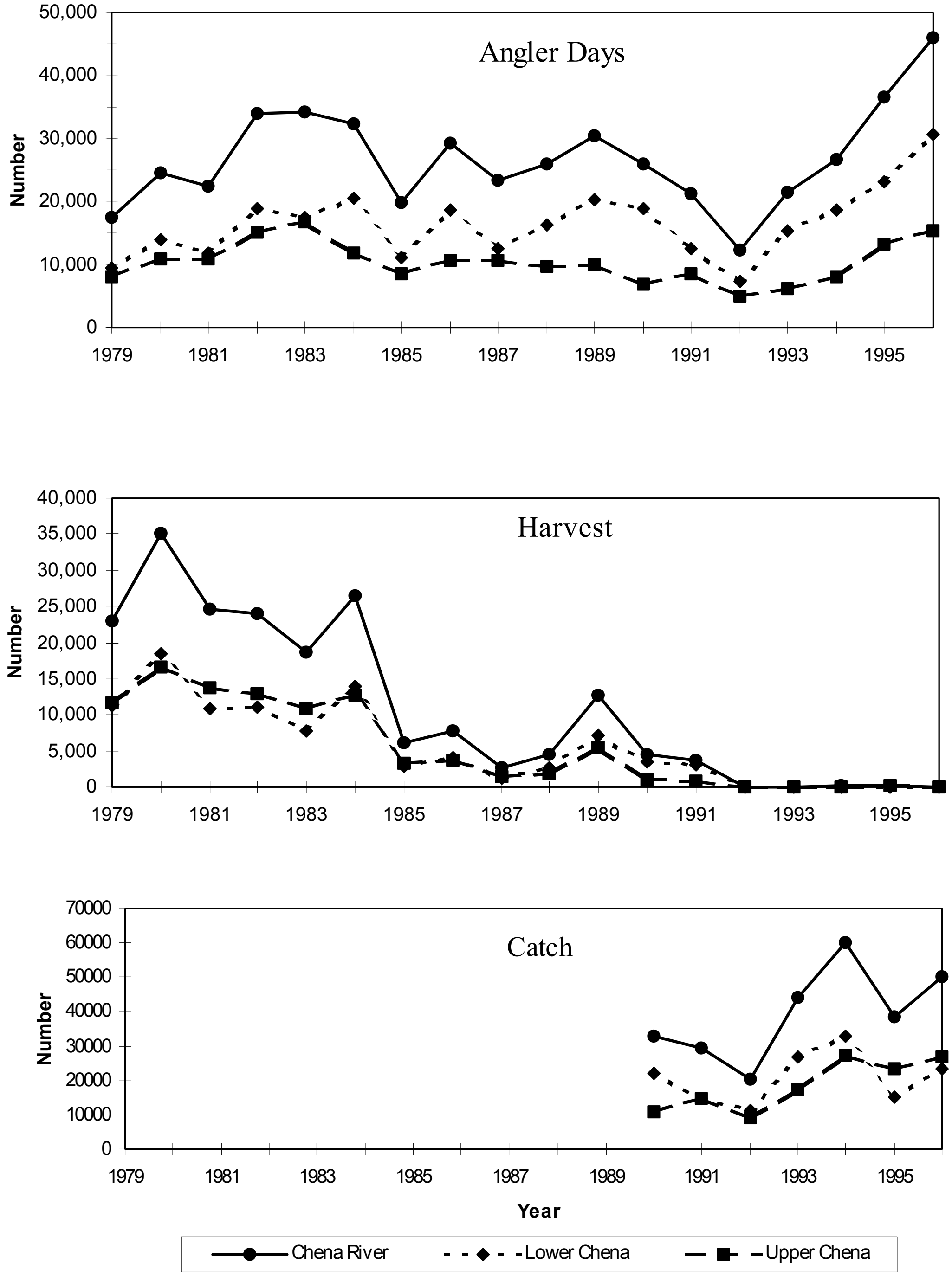

Figure 2.-Annual effort (angler days), harvest, and catch of Arctic grayling in the Chena River 1979-1996 (taken from Mills 1979-1994 and Howe et al. 1995-1997).

Along with the imposition of catch and release regulations in 1991, fishery managers began a rehabilitation program for Arctic grayling in the Chena River. The rehabilitation program had two main parts: regulation changes to ensure adequate protection of the stock, and a program of supplementation of natural production with releases of hatchery and pond-reared Arctic grayling. Beginning in spring of 1992, the first lot of fertilized eggs were taken from the Chena River stock for use in supplementing natural production. During 1993 a second lot of fertilized eggs were taken and 64,936 97-g fish (1992 brood year) were stocked into the Chena River from Clear Hatchery. During 1994, 61,435 94-g fish (1993 brood year) were stocked.

OBJECTIVES FOR STOCK ASSESSMENT

In order to accurately and precisely describe the stock status of Arctic grayling in the Chena River, the following objectives were addressed in 1997:

1. to estimate the abundance of Arctic grayling ≥ 150 mm FL in the lower 152 km[1] of the Chena River;
2. to estimate the proportion of Arctic grayling (≥ 150 mm FL) in each of four groups (wild fish, age 3 hatchery releases, age 4 hatchery releases, and age 4 pond-reared releases) in the lower 152 km[1] of the Chena River;
3. to estimate the age composition of wild Arctic grayling in the lower 152 km[1] of the Chena River; and,
4. to estimate the size composition of Arctic grayling (wild fish, age 3 hatchery releases, age 4 hatchery releases, and age 4 pond-reared releases) in the lower 152 km[1] of the Chena River.

In addition to these primary objectives, recruitment of new fish to the stock, the annual survival rate of the stock, and survival of age 3 and age 4 hatchery releases were estimated. A task of the project is to evaluate the present Chena River assessment program in regards to fiscal and biological efficiency, and this evaluation is ongoing.

METHODS

SAMPLING GEAR AND TECHNIQUES

During 1997, all sampling was performed with pulsed-DC (direct current) electrofishing systems mounted on 6.1-m-long river boats as previously described by Lorenz (1984). Input voltage (240 VAC) was provided by a 3,500 or 3,800 W single-phase gas powered generator. A variable voltage pulsator (Coffelt Manufacturing Model VVP-15) was used to generate output current. Anodes were constructed of 16.0 mm diameter and 1.5 m long twisted steel cable. Four anodes were connected to the front of a 3-m-long "T-boom" attached to a platform at the bow of the riverboat. The aluminum hull of the river boat was used as the cathode. Output voltages during sampling varied from 200 to 300 VDC. Amperage varied from 2.5 to 4.0 A. Duty cycle and pulse rate were held constant at 50% and 60 Hz, respectively. These operating characteristics were presumed to minimally affect Arctic grayling survival during mark-recapture experiments.

Sampling was conducted along the banks of the Chena River. In the Lower Chena section, two

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[1] River distance was re-estimated using a planimeter and determined to be actually 144 km not 152 km. Hereafter, the corrected distance, 144 km, will be used.

electrofishing boats were each directed downstream along one bank, capturing all Arctic grayling seen, when possible. In the Upper Chena section, one electrofishing boat was directed downstream selectively fishing one bank or the other. Due to the upper section's narrow width and frequent meanders, preferred Arctic grayling habitat is seldom along both banks. Captured Arctic grayling were held in an aerated holding tub to reduce capture related stress. The two river sections were sampled no more than once per day to prevent changes in capture probabilities of marked fish (Cross and Stott 1975). Each Arctic grayling was measured to the nearest 1 mm FL. During the second event of the mark-recapture experiments, a sample of scales was taken from an area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin of each wild Arctic grayling. In the Lower Chena section, Arctic grayling ≥ 150 mm FL were marked with a partial right pectoral clip in the first event and a partial upper caudal clip for the second event. In the Upper Chena section, Arctic grayling ≥ 150 mm FL were marked with a partial left pectoral clip in the first event and a partial lower caudal clip for the second event. All enhancement fish (hatchery and pond-reared releases) were marked with a complete fin clip (complete left or right ventral for hatchery and adipose for pond-reared releases) prior to release. If any captured Arctic grayling exhibited signs of injury or imminent mortality, they were immediately released.

ESTIMATION OF ABUNDANCE

The abundance of Arctic grayling ≥ 150 mm FL was estimated by mark-recapture techniques in the lower 144 km of the mainstem Chena River. Two sections of the Chena River were delineated for separate estimation experiments. Division of the Chena River was necessary because of differences in capture probability of Arctic grayling in different sections of river. Based on differences in capture probability from downstream to upstream areas of the Chena River, the lower 144 km of the Chena River is divided into Lower and Upper sections for estimating abundance and age composition. Downstream from the Moose Creek Dam complex to river kilometer 8 of the Chena River was designated the Lower Chena section (64 km long; Figure 3). Upstream from the dam to the first bridge on the Chena Hot Springs Road (km 62.4) was designated the Upper Chena section (80 km long; Figure 3). Population abundance estimates pertain only to these two sections of the Chena River, excluding Badger Slough, the Little Chena River, and the South Fork of the Chena River.

Abundance of Arctic grayling ≥ 150 mm FL was estimated with the modified Petersen estimator of Bailey (1951, 1952). Two electrofishing boats were used to mark Arctic grayling along both banks of the Lower Chena section and one electrofishing boat was used in the Upper Chena section. Marking of fish in each section required four days, sampling four areas within a section. After a hiatus of seven days the three electrofishing boats were used in the same way to capture marked and unmarked Arctic graying. The Upper and Lower Chena experiments were conducted concurrently during 30 June – 10 July 1997.

The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

1. the population is closed (no change in the number of Arctic grayling in the population during the estimation experiment);
2. all Arctic grayling have the same probability of capture in the first sample <u>or</u> in the second sample, <u>or</u> marked and unmarked Arctic grayling mix completely between the first and second samples;

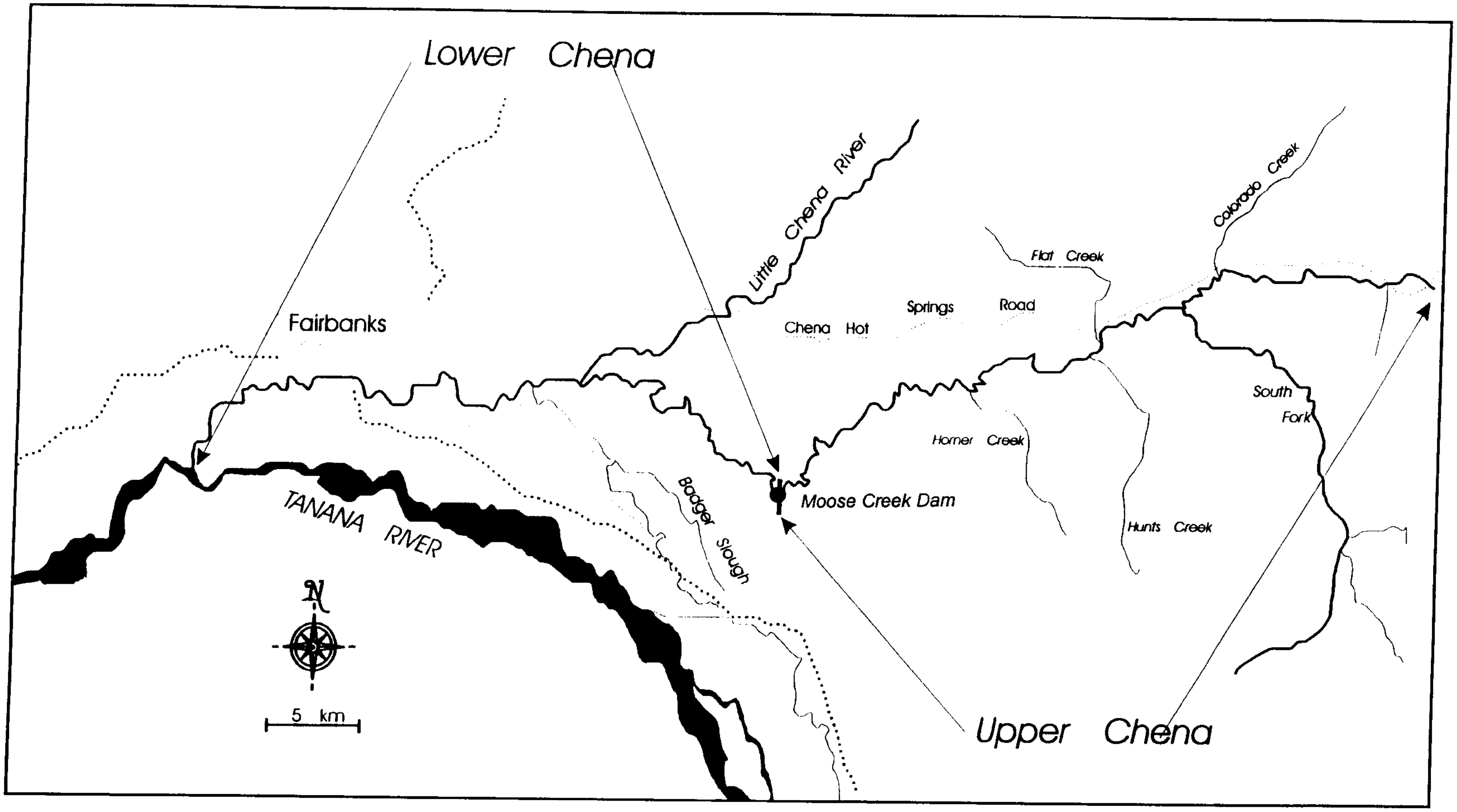


Figure 3.-Stock assessment sections in 1997 along the lower 144 km of the Chena River drainage.

3. marking of Arctic grayling does not affect their probability of capture in the second sample;
4. Arctic grayling do not lose their mark between sampling events; and,
5. all marked Arctic grayling are reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 was implicitly assumed because of the large size of the sections (64 and 80 km) and short duration of the experiments (two weeks). A large section of river reduced the probability of fish leaving the section between sampling events. The short duration reduced the likelihood that mortality or recruitment due to growth would occur between sampling events. Assumptions 4 and 5 were assumed to be valid because of double marking of tagged Arctic grayling and rigorous examination of all captured Arctic grayling.

Assumptions 2 and 3 were tested directly in three ways. First, changes in capture probability may have occurred within a section of river. These potential changes were investigated by dividing each river section into four areas, each area encompassing a near equal amount of effort (number of electrofishing runs). To determine if capture probability changed between areas, the recapture-to-catch ratios of each area were compared using a chi-squared contingency table. The four rows of the table were the different areas and the two columns of the table were the number of recaptures in the area and the number of unmarked fish examined during the second event in the same area. The experiment did not need area stratification (see Results).

Secondly, capture probability may differ by size of fish. Electrofishing is notorious for selecting for the largest fish in a population (Reynolds 1983), so that larger fish have a higher capture probability than smaller fish. Two Kolmogorov-Smirnov (KS) statistical tests were used to determine if capture probability differs by size of fish. The first KS test compared the length frequency distribution of recaptured Arctic grayling with those released with marks during the marking event. The second KS test compared the length frequency distribution of Arctic grayling captured during the marking event with those captured in the recapture event (see Bernard and Hansen 1992 for a description of tests). The first KS test was used to determine if capture probability varied by size of fish during the first (marking) event. The second KS test was used to determine if age and size data needed to be corrected for changes in capture probability (see Estimation of Age and Size Composition below). The experiment needed to be stratified by size of fish because significant size-selective sampling was detected in the second event (see Results).

Calculation of Abundance

After mark-recapture data were stratified into size with equal capture probabilities, estimated abundance was calculated from number of Arctic grayling marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$\hat{N}_i = \frac{n_1(n_2+1)}{m_2+1} \qquad (1)$$

where:

n_1 = the number of Arctic grayling marked and released alive during the first sample in stratum *i*;

n_2 = the number of Arctic grayling examined for marks during the second sample in stratum *i*;

m_2 = the number of Arctic grayling recaptured during the second sample in stratum *i*; and,

$\hat{N}_i$ = estimated abundance of Arctic grayling during the first sample in stratum *i*.

Variance was estimated by (Seber 1982):

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

Bailey's (1951, 1952) modification was used instead of the more familiar modification by Chapman (1951) because of the sampling design used on each river section. Seber (1982) found that if the assumption of a random sample for the second sample was false and a systematic sample was taken (for example, a systematic sample of both banks of the Chena River), then the bionomical model of Bailey (1951, 1952) is more appropriate.

Estimated abundance and variance of wild and hatchery fish in the lower 144 km of the Chena River was calculated as the sum of all strata (either areas, sizes, or both) from the Lower and Upper Chena sections:

$$\hat{N}_{ALL} = \sum_{i=1}^{s} \hat{N}_i \text{, and} \tag{3}$$

$$\hat{V}[\hat{N}_{ALL}] = \sum_{i=1}^{s} \hat{V}[\hat{N}_i]\,. \tag{4}$$

where:

s = the number of strata needed to alleviate bias due to changes in capture probability; and,

$\hat{N}_{ALL}$ = the estimated abundance of all fish.

Abundance of age 4 and age 5 hatchery-reared fish was estimated by apportioning the abundance of all fish by the estimated proportion of age 4 and age 5 hatchery-reared fish. First, the estimated proportion of age 4 or age 5 hatchery-reared fish in the population was estimated:

$$\hat{r}_{AGEx} = \frac{n_{AGEx}}{n_{ALL}} \tag{5}$$

where:

$\hat{r}_{AGEx}$ = the estimated proportion of age x hatchery-reared fish in the population;

n_{AGEx} = the number of age x hatchery-reared fish in the sample (n_2 from equation 1); and,

n_{ALL} = the number of fish in the sample.

Variance of this proportion was estimated as the variance of a binomial. Then the abundance of age 4 or age 5 hatchery-reared fish was estimated from the mark-recapture estimate of abundance and the estimated proportion.

$$\hat{N}_{AGEx} = \hat{r}_{AGEx}\hat{N}_{ALL} \tag{6}$$

where:

$\hat{N}_{AGEx}$ = the estimated abundance of age x hatchery-reared fish; and,

Variance of equation 6 was estimated with the formula for the variance of the product of two independent variables (Goodman 1960):

$$\hat{V}[\hat{N}_{AGEx}] = \hat{r}^2_{AGEx}\ \hat{V}[\hat{N}_{ALL}] + \hat{N}^2_{ALL}\ \hat{V}[\hat{r}_{AGEx]}] - \hat{V}[\hat{N}_{ALL}]\hat{V}[\hat{r}_{AGEx]}] \tag{7}$$

Estimates of age 4 or age 5 hatchery-reared fish were then summed by river section as in equations 3 and 4.

ESTIMATION OF AGE AND LENGTH COMPOSITION

Collections of wild Arctic grayling for age-length samples were conducted in conjunction with abundance estimation experiments. Age composition was described with proportions of the stock contained in each age class from 2 through 12 years (third through thirteenth summers). Size composition of Arctic grayling in each of the river sections was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories are: “stock” (150 to 269 mm FL); “quality” (270 to 339 mm FL); “preferred” (340 to 449 mm FL); “memorable” (450 to 559 mm FL); and, “trophy” (greater than 559 mm FL). Incremental size composition was also estimated for each 10 mm increment of fork length from 150 mm to 450 mm. Incremental size composition was also used to describe the sizes of hatchery-reared fish sampled in the Chena River.

From tests of assumptions 2 and 3 for estimation of abundance, significant differences in capture probability by size of fish were found. Differences in capture probability may also bias estimates of age and size compositions. Age and size data were adjusted for these differences so that the age and size composition of Arctic graying in the lower 144 km of the Chena river could be estimated. First, the proportions of fish by age class or size category were estimated for each stratum used in estimation of abundance:

$$\hat{p}_{ik} = \frac{n_{ik}}{n_i} \tag{8}$$

where:

$\hat{p}_{ik}$ = the estimated proportion in age or size category *k* fish sampled in stratum *i*;

n_{ik} = the number of age or size category *k* fish sampled in stratum *i*; and,

n_i = the number of fish sampled in stratum *i*.

Variance of this proportion was estimated as the variance of a binomial. Next the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_{ik} = \hat{p}_{ik}\hat{N}_i \qquad (9)$$

where:

$\hat{N}_{ik}$ = the estimated abundance of age or size category *k* fish sampled in stratum *i*.

Variance of each abundance at age or size was estimated with the formula for the variance of the product of two independent variables (as in equation 7). After calculating abundances at age or size in each stratum, the overall proportions were estimated by:

$$\hat{\hat{p}}_k = \sum_{i=1}^{s} \frac{\hat{N}_i}{\hat{N}_{ALL}} \hat{p}_{ik} \qquad (10)$$

where:

$\hat{\hat{p}}_k$ = the estimated weighted proportion of Arctic grayling in the lower 152 km of the Chena River that were age or size *k*.

Variance of the proportions were approximated with the delta method (see Seber 1982):

$$\hat{V}[\hat{\hat{p}}_k] \approx \sum_{i=1}^{s} \frac{(\hat{p}_{ik} - \hat{\hat{p}}_k)^2 \ \hat{V}[\hat{N}_i]}{\hat{N}_{ALL}^{\ 2}} + \sum_{i=1}^{s} \left(\frac{\hat{N}_i}{\hat{N}_{ALL}} \right)^2 \hat{V}[\hat{p}_{ik}] \qquad (11)$$

These estimated weighted proportions and variances by age and size were used as estimates of age and size compositions in the lower 144 km of the Chena River.

Estimation of Survival and Recruitment

As of 1997, 12 years of population abundance and age composition estimates had been completed for the lower 144 km of the Chena River. Using data from 1986 through 1996, Ridder (1997) reported on survival rates and recruitment for 1986 through 1996. Survival rate and recruitment for 1997 was calculated in the same manner.

Annual recruitment was defined as the number of age-3 Arctic grayling added to the population between year *t* and year *t+1*, and alive in year *t+1*. Estimates of recruitment were simply the estimates of abundance of age-3 Arctic grayling in 1996 and 1997. Variance of the recruitment estimates were the variance of abundance at age-3 for these same years.

With recruitment and abundance at age estimates in years *t* and *t+1*, the estimate of survival rate between year *t* and year *t+1* was:

$$\hat{S}_{t,t+1} = \frac{\hat{N}'_{t+1}}{\hat{N}_t} \qquad (12)$$

where: $\hat{N}'_{t+1} = \sum_{k=4}^{12} \hat{N}_{t+1,k} =$ the abundance of age *k* and older Arctic grayling in year *t+1*; and,

$$\hat{N}_t = \sum_{k=3}^{12} \hat{N}_{t,k} \quad = \quad \text{the abundance of age } k \text{ and older Arctic grayling in year } t.$$

The variance of annual survival was approximated as the variance of a quotient of two independent variables with the delta method (Seber 1982):

$$\hat{V}[\hat{S}] \approx \left[\frac{\hat{N}'_{t+1}}{\hat{N}_t}\right]^2 \left[\frac{\hat{V}[\hat{N}'_{t+1}]}{\hat{N}'^{2}_{t+1}} + \frac{\hat{V}[\hat{N}_t]}{\hat{N}^2_t}\right] \quad (13)$$

where: $$\hat{V}[\hat{N}'_{t+1}] = \sum_{k=4}^{12} \hat{V}[\hat{N}'_{t+1,k}]; \text{and, } \hat{V}[\hat{N}_t] = \sum_{k=3}^{12} \hat{V}[\hat{N}_{t,k}]. \quad (14)$$

Variances in equation 14 are slightly inflated due to missing covariance terms; inferences from these variances are therefore conservative.

HISTORIC DATA SUMMARY

Data collected from the Chena River (1955 to 1996) are summarized in Appendix A. Creel survey estimates, population abundance estimates, length at age estimates, age composition estimates, size composition estimates, and a model of Arctic grayling growth were summarized from Federal Aid in Sport Fish Restoration reports and State of Alaska Fishery Data Series reports written from 1959 to 1997 (Appendix A2). When possible, estimates of precision were reported with point estimates. Precision was reported as either standard error or 95% confidence interval. Sample sizes were reported if neither of these estimates of precision were available. Length frequency was generally reported in the literature as numbers sampled per 10 mm length increment. The length frequency distributions were converted into the RSD categories of Gabelhouse (1984) for comparison with data collected from 1986 to 1996. In addition to the aforementioned reports in Appendix A2, Arctic grayling migration studies were summarized in a report by Tack (1980). Reports concerning Arctic grayling research from 1952-1980 were compiled by Armstrong (1982). Armstrong et al. (1986) have compiled a bibliography for the genus *Thymallus* to 1985. In addition, Clark (1992b) estimated age and size at maturity for the Chena River stock in 1991 and 1992, and Clark (1993) estimated interannual intrastream movements of tagged fish in the Chena River for 1987 through 1992. A list of electronic data files used in analyses for 1997 are found in Appendix B1.

RESULTS

The stock assessment of the Chena River in 1997 was conducted concurrently in both the lower and upper Chena River study sections with the first (marking) event occurring from 30 June through 3 July and the second sampling (recapture) event from 7 through 10 July. River discharge was extremely low during both events. Discharge from 1 through 10 July 1997 at the United States Geological Survey (USGS) gauging station at river kilometer 144 ranged from 6.8 cubic meters per second (cms) to 9.2 cms (Figure 4) and averaged 7.6 cms which was the lowest in 28 years (Figure 5). This low water severely hampered navigability in the upper study section and was likely one cause of the lowest catches experienced with the present sampling methodology (Appendix A3). Coupled with the low discharge, extreme high flows in the Tanana

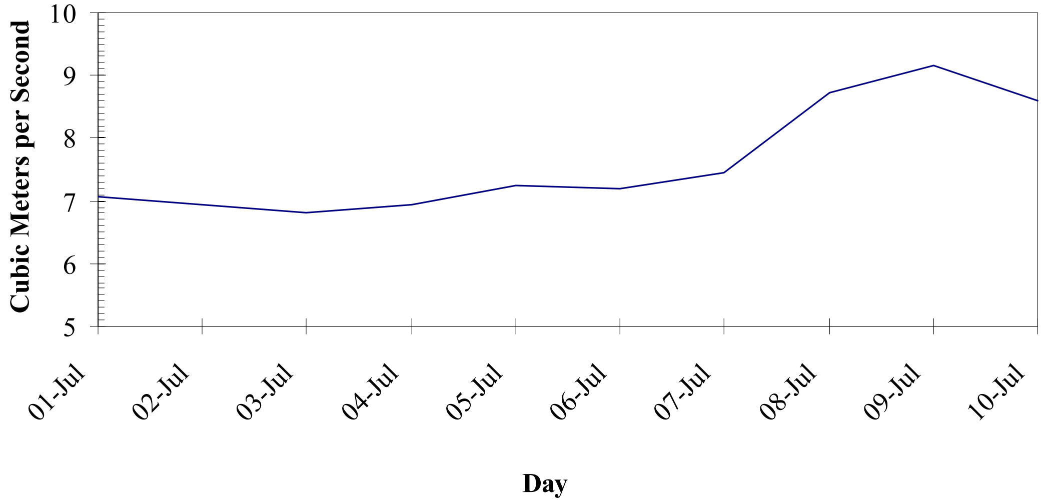


Figure 4.-Daily discharge (cms) for the Chena River at river km 152 for 1 - 10 July 1997. from USGS: http://www.water.usgs.gov/swr/ak/ ?statnum=15493000; 1997 data from M. Schellenkens, USGS, unpubl.)

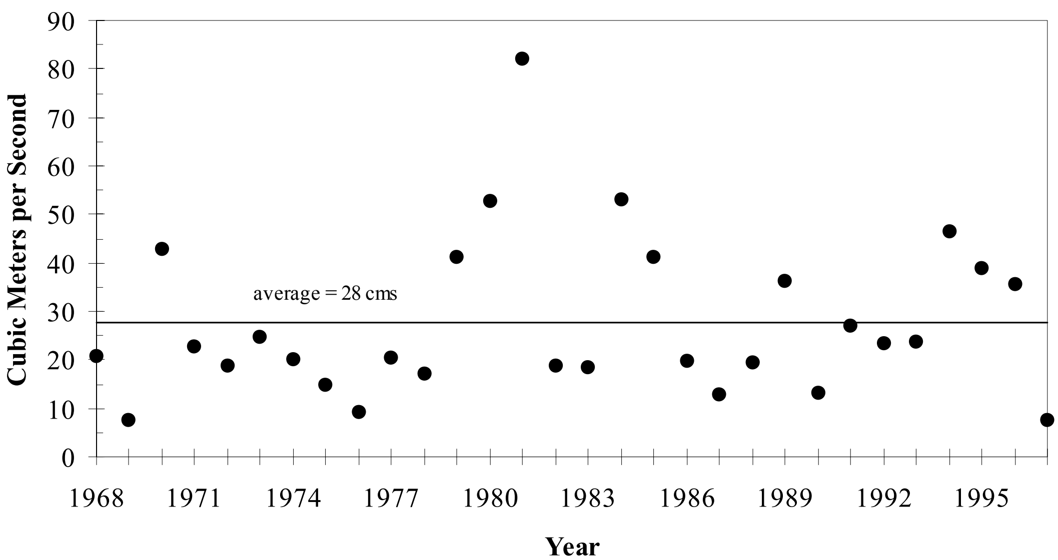


Figure 5.-Average discharge (cms) for the Chena River at river km 152 for 1 - 10 July 1968 – 1997. (1968-1996 data from USGS: http://www.water.usgs.gov/swr/ak/ ?statnum=15493000; 1997 data from M. Schellenkens, USGS, unpubl.)

River during the period created a damming effect in the lower river that produced minimal water velocities and catches from the Trainor Gate bridge at river kilometer 24 to the lower study boundary at river kilometer 8. From 1991 through 1996, this 16 km reach provided 15% to 25% of the total lower river catch and averaged 20% (SE = 1%, Appendix A4). The 1997 catch in this reach was significantly lower at 9% (SE = 1%) than any of the preceding years.

Water temperatures (°C) during stock assessment were also extreme, being the highest recorded since 1991:

	Lower Chena River				Upper Chena River			
Year	n[a]	Low	High	Average	n	Low	High	Average
1991	3	12.5	14.5	13.2	na	---	---	---
1992	8	12.1	14.0	13.2	9	9.0	12.5	10.8
1993	11	12.2	16.0	13.7	8	9.2	13.0	11.8
1994	10	9.2	14.1	11.3	8	8.5	11.2	10.2
1995	na	---	---	---	5	8.0	10.0	9.6
1996	5	11.8	13.5	12.9	na	---	---	---
1997	9	14.5	18.7	16.1	14	10.9	16.2	13.2

[a] n= number of observations.

These high temperatures coupled with low flows may have impacted the experiment via differential mortality between marked and unmarked fish and/or behavioral modifications affecting availability of fish. Capture probabilities and recapture rates in 1997 were the lowest since 1987 (Appendix A3).

Lower Chena Section

The Lower Chena experiment captured 1,311 Arctic grayling over the eight days of sampling. Twenty-three immediate mortalities or serious injuries were recorded for an injury rate of 1.8%. A total of 673 fish were marked and released alive, 581 fish were examined for marks, and 34 fish were recaptured. A chi-square test showed recapture-to-catch ratios did not vary significantly among eight areas (χ^2 = 4.07, df = 3, P ≈ 0.25; Figure 6) indicating area stratification was unnecessary, but only one fish was recaptured in the lowest area. Despite the small recapture rate in the lowest area, all areas were combined for the experiment since the sum of area abundances, 11,068 fish (SE = 1,950 fish), was not significantly different than the unstratified abundance, 11,191 fish (SE = 1,808 fish). The experiment was stratified by size of fish since comparisons of length frequencies of marked fish with that of recaptured fish inferred that there was significant size-selective sampling in the second event (D = 0.28, P ≈ 0.01; Figure 7). The maximal chi-squared statistic occurred at a stratification of 150 to 240 mm FL for small fish and >240 mm FL for large fish. Summing estimates of abundance from the two strata (Table 2), abundance of all Arctic grayling ≥150 mm FL in the Lower Chena was 12,434 (SE = 2,444). Abundance of wild fish was 12,249 (SE = 2,431) and abundance of age 4 hatchery-reared fish was 73 (SE = 26) or 0.8% of the combined abundance (Table 3). Abundance of age 5 hatchery-reared fish was 112 fish (SE = 34 fish) or 1.4% of the combined abundance (Table 3).

There was no significant difference in the length frequencies of fish marked versus those examined for marks in the Lower Chena section (D = 0.08, P ≈ 0.30; Figure 7). Therefore samples from both events could be pooled to estimate age composition of wild fish and size

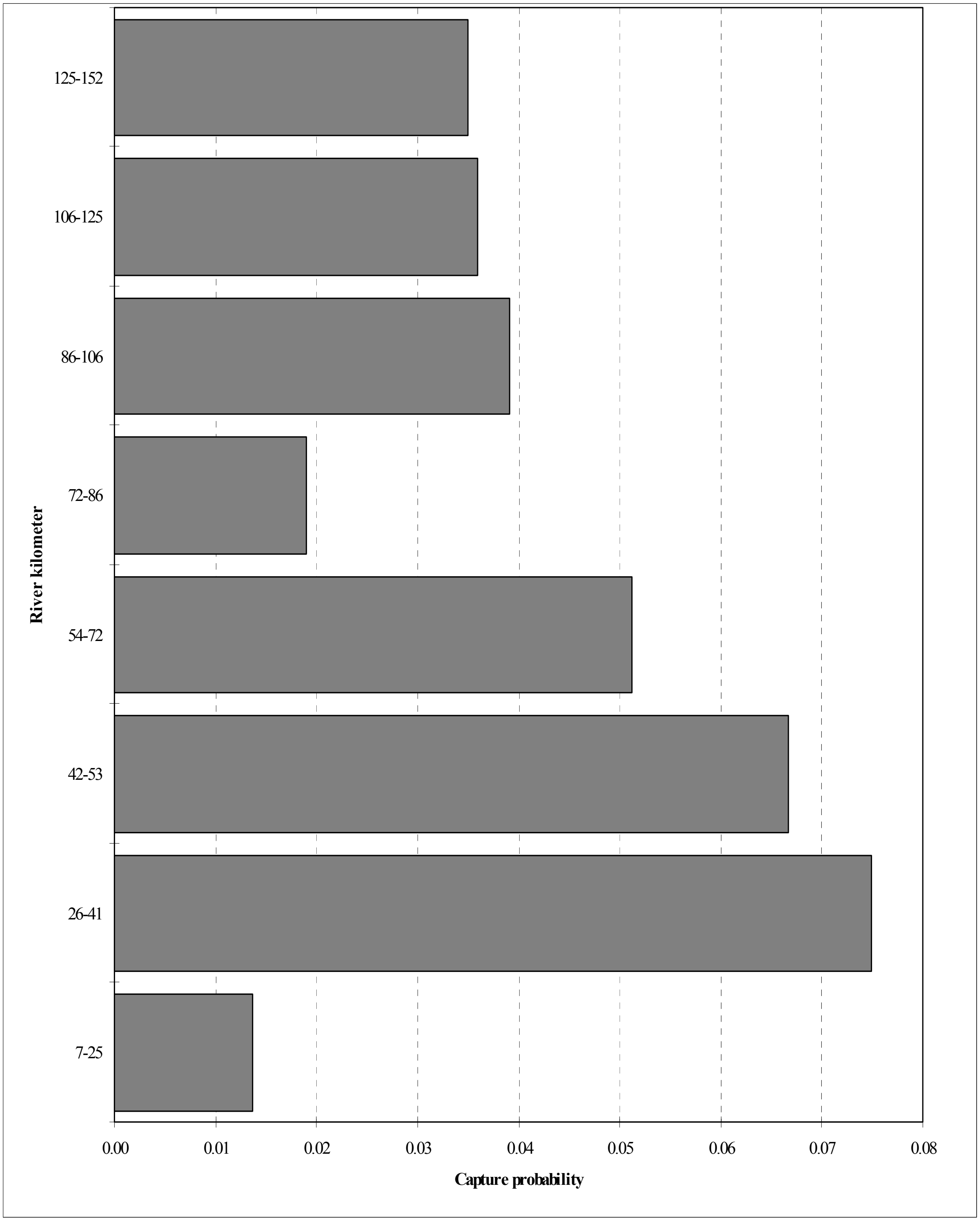
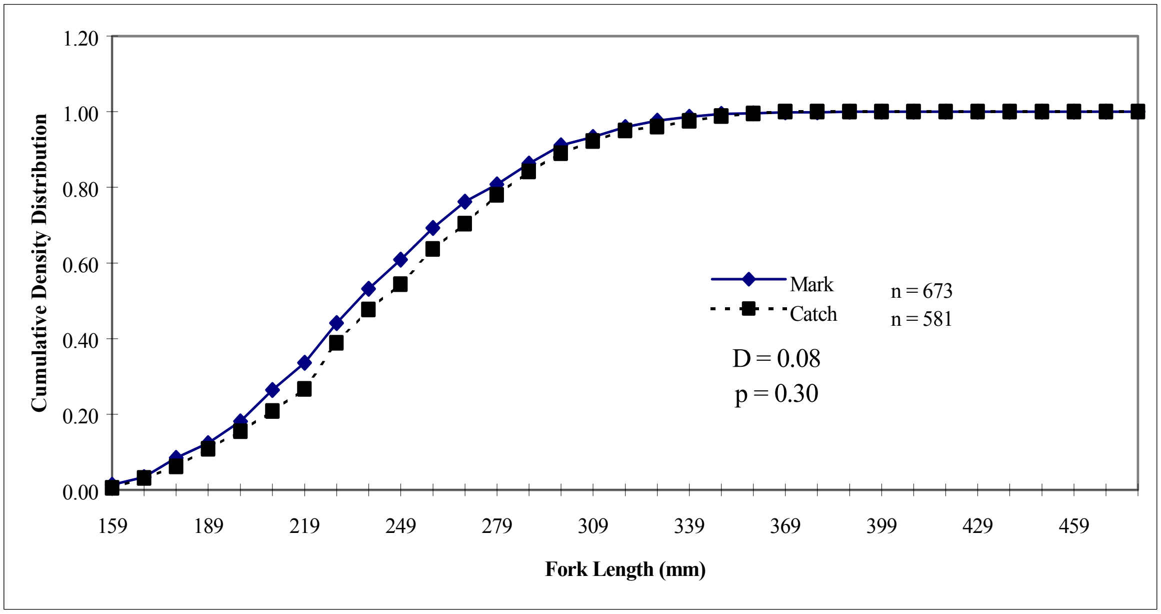


Figure 6.-Recapture-to-catch ratios of Arctic grayling (≥150 mm FL) in eight reaches of the Chena River in 1997.



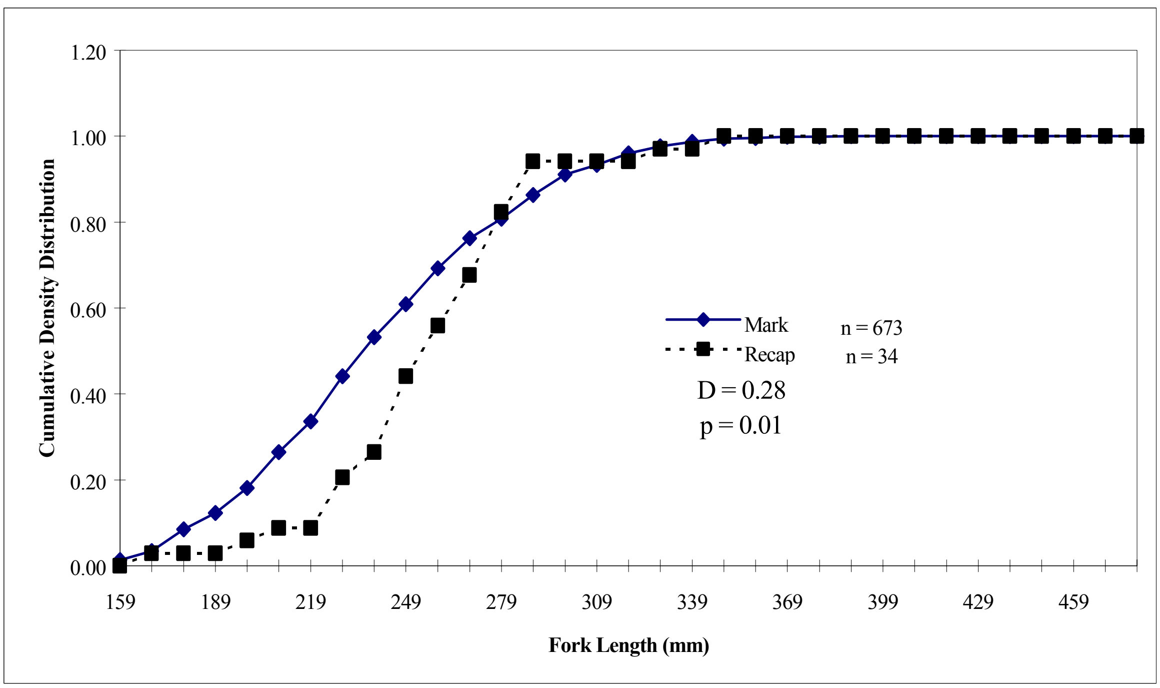


Figure 7.-Cumulative density distributions of fork length of Arctic grayling marked, captured, and recaptured in the Lower Chena section of the Chena River, 30 June through 10 July 1997.

Table 2.-Capture probabilities and estimated abundance used for population estimation of Arctic grayling (≥ 150 mm FL) in the Lower and Upper Chena sections of the Chena River study area, 30 June through 10 July 1997.

Section	Stratum	Mark (n_1)	Catch (n_2)	Recap (m_3)	m_2/ n_2[a]	N[b]	SE[N][c]
Lower	Small[d]	364	282	11	0.04	8,584	2,330
	Large[e]	309	298	23	0.07	3,850	738
	Total	673	581	34	0.05	12,434	2,444
Upper	Small	201	218	0	0	nd	---
	Large	504	645	22	0.03	14,156	2,838
	Total	705	863	22	0.03	nd	---

[a] m_2/n_2 is the probability of capture.

[b] N is the estimated abundance in a stratum.

[c] SE [N] is the standard error of N.

[d] Small is fish 150 - 240 mm FL.

[e] Large is fish > 240 mm FL.

Table 3.-Estimates of apportioned abundance in three strata used for population estimation of wild, age-4 hatchery-reared, and age-5 hatchery-reared Arctic grayling (≥ 150 mm FL) in the Lower and Upper Chena sections of the Chena River, 30 June through 10 July 1997.

	Lower Chena			Upper Chena			
	150-240 mm	> 240 mm	All	150-239 mm	> 239 mm	All	Total
Catch:[a]							
AGE4	1	9	10	0	8	8	18
AGE5	0	17	17	0	22	22	39
Wild	634	559	1,193	419	1,097	1516	2,709
All	635	585	1,220	419	1,127	1546	2,766
pAGE4[b]	<0.01	0.02	0.01	0	<0.01	0.01	0.01
SE	<0.01	0.01	<0.01	---	<0.01	<0.01	<0.01
pAGE5[b]	0	0.03	0.01	0	0.02	0.01	0.01
SE	---	0.01	<0.01	---	<0.01	<0.01	<0.01
Abundance:[c]							
AGE4	14	59	73	0	100	100	173
SE	14	22	26	---	40	40	48
AGE5	0	112	112	0	276	276	388
SE	---	34	34	---	80	80	87
Wild	8,570	3,679	12,249	na[d]	13,779	na	na
SE	2,326	706	2,431	---	2,924	na	na
All	8,584	3,850	12,434	na	14,156	na	na
SE	2,330	738	2,444	---	2,838	na	na

[a] Catches are of age-4 hatchery-reared fish (AGE4), age-5 hatchery-reared fish (AGE5), wild fish (Wild), and all fish (All). In both Chena sections, catches are from pooled events minus recaptures.

[b] pAGEx is the proportion of age-x hatchery-reared fish in the catches of All fish (AGEx divided by All).

[c] Abundances are of age-4 hatchery-reared fish (AGE4), age-5 hatchery-reared fish (AGE5), wild fish (Wild), and all fish (All).

[d] na = not available. No recaptures in the small fish category precluded abundance estimates.

compositions of wild and hatchery-reared fish. However, samples of ages were only taken during the second event so that age compositions were estimated from the second (recapture) event only while size compositions were estimated from both events. An estimated 37% of the population was wild age 4 fish (Table 4). Ages 2 through 5 contributed 82% of abundance with very few fish older than age 7. Similarly, stock size wild fish contributed 83% of the abundance in the Lower Chena while 1% of fish were of preferred size (Table 5). Age 4 hatchery fish (1993 brood, n = 10 from both events) ranged from 233 to 290 mm FL with a mean length of 265 mm FL (SD = 17, Table 6). Age 5 hatchery fish (1992 brood, n = 17 from both events) ranged from 242 to 319 mm FL with a mean length of 270 mm FL (SD = 22, Table 6).

Upper Chena Section

The Upper Chena experiment captured 1,617 Arctic grayling out of which 27 immediate mortalities or serious injuries were recorded for an estimated injury rate of 1.7%. A total of 705 fish were marked and released alive, and 863 fish were examined for marks of which 22 fish were recaptures. The experiment did not need area stratification since recapture-to-catch ratios did not differ significantly among four areas of the Upper Chena ($\chi 2 = 1.64$, df = 3, P ≈ 0.64; Figure 8).

The objective of estimating parameters for fish ≥150 mm FL had to be truncated to fish ≥ 240 mm since the smallest recaptured fish was 242 mm despite 29% of the mark and 25% of the catch being smaller (Table 2). This truncation did not alter the capture probabilities within the four areas which remained similar ($\chi^2 = 0.92$, df = 3, P ≈ 0.82).

Length stratification of the truncated experiment was unnecessary as size selective sampling bias was not found in either event. There was no difference in length frequencies of fish marked versus those recaptured nor of fish marked versus those examined for marks (D = 0.20, P ≈ 0.39 and D = 0.06, P ≈ 0.36, respectively; Figure 8). The estimate of abundance of fish ≥240 mm in the Upper Chena was 14,156 (SE = 2,838; Table 2). The population included 0.7% age 4 hatchery-reared fish and 2% age 5 hatchery-reared fish (Table 3). Abundance of wild fish ≥240 mm was 13,799 (SE = 2,924) and abundance of age 4 hatchery-reared fish was 100 (SE = 40; Table 3). Abundance of age 5 hatchery-reared fish was 276 (SE = 80; Table 3). The estimated abundance of hatchery reared fish is assumed representative of all hatchery fish present in the Upper Chena section. While the fact that no hatchery fish less than 240 mm were captured does not mean no small hatchery fish were present, it does suggest that their number is likely very small and would not add additional variability to the estimated abundance.

Without evidence for size-selective sampling, age and size compositions for the truncated population could be estimated from pooled events, though only size compositions were so estimated; age compositions were estimated from the second event (aging data was only collected during the second event). While ten age classes were present in the sample of fish, only nine classes were in the sample of fish ≥240 mm (Table 7). Age 6 fish were predominant, contributing 29% of the estimated abundance of fish ≥240 mm. Ages 5 and 6 fish ≥240 mm contributed 97.4% and 98.7%, respectively, of all age 5 and 6 fish ≥150 mm sampled (Table 7) and their estimated abundances can be compared to historical estimates without significant bias. While stock size fish (150 - 270 mm FL) contributed 50% of the sample, the truncation of the database to fish ≥240 mm precluded accurate RSD estimates of size composition (Table 5). However, valid estimates of abundance of quality and preferred sized fish were made. There were 8,252 quality sized fish (SE = 1,667 fish) and 1,206 preferred sized fish (SE = 268 fish) in

Table 4.-Estimates of age composition, length at age, and abundance by age class with standard errors for wild Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the Lower Chena section of the Chena River, 30 June through 10 July 1997.

	Age Composition				Length at Age (mm FL)				Abundance		
Age	n[a]	p[b]	p'[c]	SE[p']	Mean	SD	Min	Max	N[d]	SE[N]	CV(%)[e]
2	41	0.08	0.11	0.02	172	9	150	190	1,357	413	30
3	75	0.15	0.20	0.03	199	14	171	256	2,463	704	29
4	154	0.30	0.37	0.03	230	17	190	337	4,585	1,165	25
5	95	00.19	0.14	0.02	259	19	222	318	1,665	307	18
6	62	0.12	0.08	0.02	274	20	218	322	975	204	21
7	26	0.05	0.03	0.01	292	22	238	346	404	105	26
8	22	0.04	0.03	0.01	301	17	274	330	326	91	28
9	18	0.04	0.02	0.01	314	24	285	359	267	79	29
10	7	0.01	0.01	0.00	333	15	313	351	104	43	41
11	1	0.00	0.00	0.00	339	---	339	339	15	15	100
12	4	0.01	0.00	0.00	342	21	318	360	59	31	52
13	2	0.00	0.00	0.00	348	18	335	361	30	21	72
Total	507	1.00	1.00		244	43	150	361	12,249	2,431	20

[a] n= number of Arctic grayling sampled at age.

[b] p= estimated proportion of Arctic grayling at age in the sample.

[c] p'= estimated adjusted proportion of Arctic grayling at age in the population.

[d] N= estimated population abundance of Arctic grayling at age.

[e] CV = coefficient of variation.

Table 5.-Summary of Relative Stock Density (RSD) indices of wild Arctic grayling (≥ 150 mm FL) captured in A: the Lower Chena section, B: the Upper Chena section, and C: the Chena River study area, 1997.

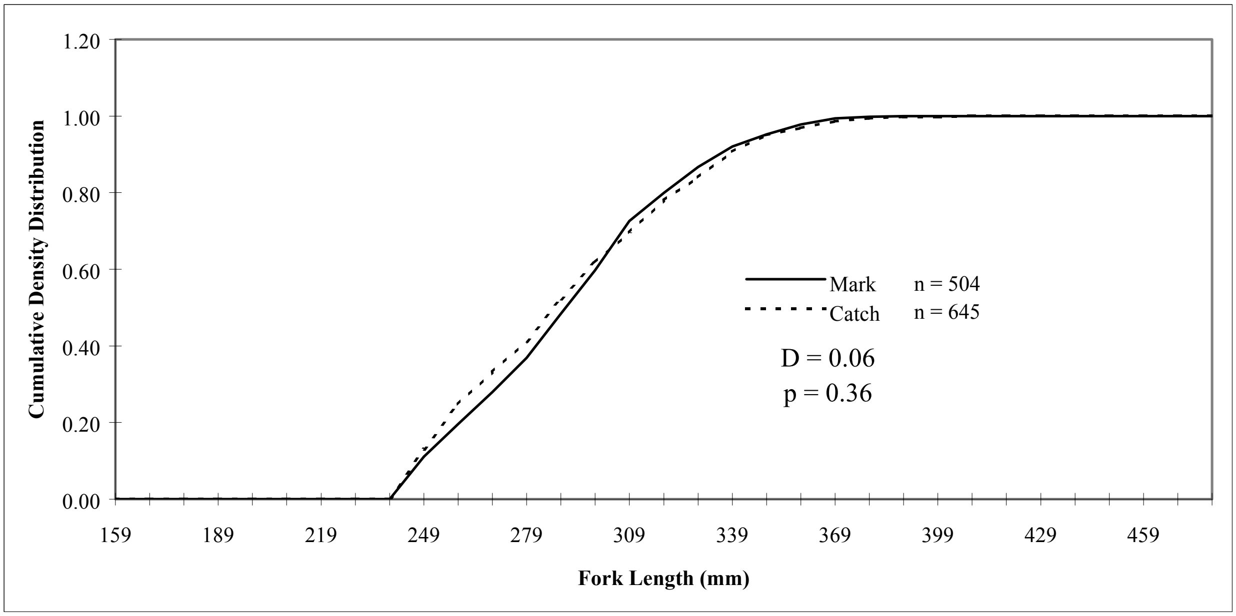
		RSD Category[a]				
		Stock	Quality	Preferred	Memorable	Trophy
A:	Number Sampled	882	288	22	0	0
	RSD	0.74	0.24	0.02	---	---
	Adjusted RSD[b]	0.83	0.16	0.01	---	---
	SE (RSD)	0.04	0.04	<0.01	---	---
	N	10,205	1,899	145	0	0
	SE (N)	2,348	372	41	---	---
B:	Number Sampled ≥150	763	657	96	0	0
	RSD	0.50	0.43	0.06	---	---
	Adjusted RSD[b]	unk	unk	unk	---	---
	SE (RSD)	0.01	0.01	0.01	---	---
	N	na	8,252	1,206	0	0
	SE (N)	---	1,667	268	---	---
C:	Number Sampled	1,645	945	118	0	0
	RSD	0.61	0.35	0.04	---	---
	Adjusted RSD[b]	na	na	na	---	---
	SE (RSD)	---	---	---	---	---
	N	na	10,141	1,351	0	0
	SE (N)	---	1,708	271	---	---

[a] Minimum lengths for RSD categories are (Gabelhouse 1984): Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.

[b] Adjusted RSD is the RSD corrected for differential vulnerability by length from electrofishing. Standard error of RSD is for the adjusted estimate.

Table 6.-Length composition of age-4 (1993 Brood) and age-5 (1992 Brood) hatchery reared Arctic grayling in the Lower and Upper Chena sections of the Chena River study area, July 1997.

Brood	Area	n	mean	SD	Min	Max
1992	Lower Chena	17	270	22	242	319
1992	Upper Chena	22	296	18	254	318
	Both	39	285	23	242	319
1993	Lower Chena	10	265	17	233	290
1993	Upper Chena	8	275	22	254	301
	Both	18	270	20	233	301



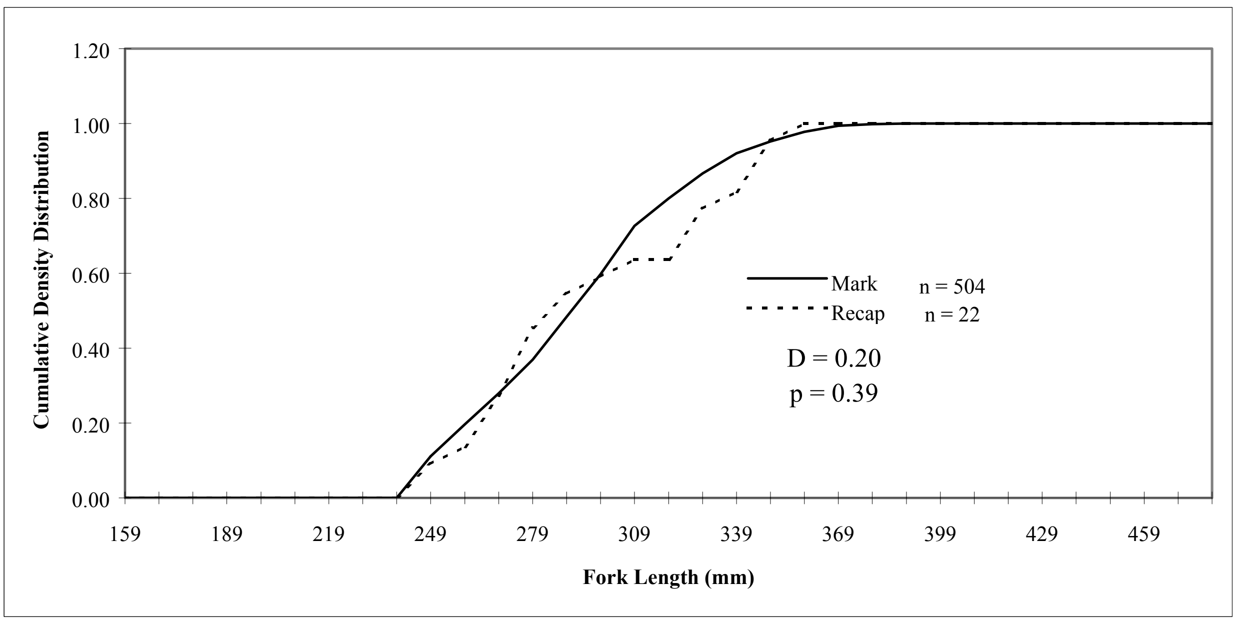


Figure 8.-Cumulative density distributions of fork length of Arctic grayling marked, captured, and recaptured in the Upper Chena section of the Chena River, 30 June through 10 July 1997.

Table 7.-Estimates of age composition, length at age and abundance by age class with standard errors for wild Arctic grayling captured by pulsed-DC electrofishing from the Upper Chena section of the Chena River, 30 June through 10 July 1997.

	Age Composition					Length at Age (mm FL) for fish ≥ 240 mm FL				Abundance for fish ≥ 240 mm FL		
	Fish ≥ 150 mm FL		Fish ≥240 mm FL									
Age	n[a]	p[b]	n	p	SE[p]	Mean	SD	Min	Max	N[c]	SE[N]	CV(%)[d]
2	6	0.01	0	0	---	162	9	153	175	0	---	---
3	59	0.08	1	0.00	0.00	204	16	156	253	27	27	100
4	252	0.36	136	0.27	0.02	240	16	197	284	3,667	781	21
5	78	0.11	76	0.15	0.02	272	18	237	320	2,049	463	23
6	149	0.21	147	0.29	0.02	295	23	229	337	3,964	840	21
7	89	0.13	89	0.17	0.02	313	24	252	366	2,400	532	22
8	35	0.05	35	0.07	0.01	323	25	280	369	944	242	26
9	27	0.02	17	0.03	0.01	344	20	297	383	458	141	31
10	8	0.01	8	0.02	0.01	362	19	322	385	216	86	40
11	2	0.00	2	0.00	0.00	395	11	387	402	54	39	72
Total	695	1.00	511	1.00	---	271	45	153	402	13,779	2,763	20

[a] n = number of Arctic grayling.

[b] p = estimated proportion of Arctic grayling at age in the sample.

[c] N = estimated population abundance.

[d] CV = coefficient of variation.

the Upper Chena section (Table 5). Lengths of age 4 hatchery fish (1993 brood, n = 8) ranged between 254 mm and 301 mm with a mean of 275 mm FL (SD = 22; Table 6). Lengths of age 5 hatchery fish (1992 brood, n = 22) ranged between 254 mm and 318 mm with a mean of 296 mm (SD = 18; Table 6).

Chena River Total

Summing estimated abundances from the Lower and Upper Chena sections, there were a minimum of 26,028 wild fish (SE = 3,680 fish; Table 8) in the Chena River in 1997. The estimated abundance was a minimum because age classes 2 through 4 were underestimated due to the exclusion of small fish $\geq$240 mm in the estimates derived from the Upper section (see Table 7). However, the estimated 13,857 fish (SE = 1,205 fish) of ages 5 and older was near inclusive for these age classes and considered unbiased by the exclusion of small fish.

Survival and recruitment rates have been presented in past reports for age-3 and older Arctic grayling but could not be estimated in 1997 due to the above deficiencies in parameter estimates in the Upper Chena section. However, survival and recruitment estimates for age-5 and older fish were obtained for the Chena River study area in 1997. Survival rate of age-5 and older fish from 1996 to 1997 was 51.3% (SE = 6.3, Table 9). Recruitment from 1996 to 1997 (age-5 fish) was 3,774 fish (SE = 560 fish, Table 9).

Size composition within the RSD categories could not be accurately estimated for the Chena River study area again due the above exclusion of small fish from the upper section. However, abundance of quality sized and larger fish ($\geq$270 mm FL) was inclusive and estimated at 11,492 fish (SE = 1,729 fish: Table 5).

Hatchery-reared fish contributed 2.1% of the sample, with an estimated abundance of 173 age-4 and 388 age-5 fish (SE = 48 and 87, respectively; Table 3). Estimated survival of age-4 hatchery-reared fish (1993 Brood) from time of release in June 1994 (61,435 fish) to time of stock assessment in July 1997 was 0.3% (SE = <0.1%; Table 10). Estimated survival of age 5 hatchery-reared fish (1992 Brood) from time of release in June 1993 (64,936 fish) to time of stock assessment in July 1997 was 0.6% (SE = <0.1%; Table 10). Annual survival of age-4 hatchery-reared fish (July 1996 to July 1997) was 30.2% (SE = 3.3%) while annual survival of age-5 hatchery-reared fish was 47.6% (SE = 3.5%; Table 10). Age-4 hatchery-reared fish ranged in length from 233 mm to 301 mm and averaged 270 mm (Table 10). Age-5 hatchery-reared fish ranged in length from 242 mm to 319 mm and averaged 285 mm (Table 10).

Because size selective sampling was found in the lower river and occurred to such an extent in the upper river that samples had to be truncated, $\hat{r}_{AGEx}$ is biased. However, because $\hat{r}_{AGEx} < 0.01$, this bias is obviously small and does not change the inference about the failure of enhancement to enhance.

DISCUSSION

STOCK STATUS

The 1997 stock assessment of the lower 144 km of the Chena River was compromised by poor water conditions. High water temperatures coupled with extremely low flow in the Upper Chena and lacustrine-like water in the Lower Chena resulted in the lowest capture probabilities since the inception of whole river sampling (Appendix A3). This inability to capture fish, especially small fish, resulted in a failure to estimate two major parameters of the assessment program:

Table 8.-Age composition and abundance estimates by age class for wild Arctic grayling captured by pulsed-DC electrofishing from the Chena River, 30 June through 10 July 1997. Due to exclusion of fish < 240 mm FL from the Upper river section, age compositions are biased towards older fish and abundances for age classes 2 through 4 are biased low.

Age Class	N[a]	V [N]	SE [N]	p[b]	SE [p]
2	1,351	169,451	412	0.05	0.01
3	2,480	492,747	702	0.10	0.02
4	8,339	1,981,592	1,408	0.32	0.02
5	3,774	313,126	560	0.15	0.01
6	4,882	740,929	861	0.19	0.02
7	2,780	292,702	541	0.11	0.02
8	1,249	65,806	257	0.05	0.01
9	708	25,368	159	0.03	0.01
10	313	8,995	95	0.01	<0.01
11	68	1,703	41	<0.01	<0.01
12	56	848	29	<0.01	<0.01
13	28	398	20	<0.01	<0.01
Total	26,028	4,094,665	3,680		
Age 5+	13,857	1,450,874	1,205		
Age 6+	10,083	1,137,749	1,067		

[a] N = estimated population abundance of Arctic grayling at age.

[b] p = estimated adjusted proportion of Arctic grayling at age.

Table 9.-Summary of population abundance, annual survival (%), annual recruitment, and standard error estimates during 1987-1997 for wild Arctic grayling (≥ age-5) in the lower 144 km of the Chena River.

Year	N[a]	SE [N]	S[b]	SE [S]	B[c]	SE [B]
1987	8,292		59.1	4.4	2,370	511
1988	14,327	940	46.9		9,423	868
1989	9,279		71.2	9.2	2,563	
1990	9,034	987	54.4	7.9	2,429	489
1991	7,883	621	54.0	5.8	2,966	404
1992	15,437	1,120	44.3	7.2	11,178	1,077
1993	10,357	1,184	77.1	10.6	3,520	632
1994	11,164	697	50.1	5.8	3,178	343
1995	14,063	1,168	91.3	9.5	8,471	1,033
1996	19,668	1,206	51.3	6.3	6,834	892
1997	13,857	1,205			3,774	560
Averages[d]:	12,124	1,014	58.4	7.1	5,155	681
1987-1990	10,233	963	57.2	6.8	4,196	623
1991-1997	13,204	1,029	59.2	7.3	5,703	706

[a] N is the abundance of age-5 and older Arctic grayling.

[b] S is the survival from that year to the next year.

[c] B is recruitment of age-5 Arctic grayling during that year.

[d] Average of survival rate is the geometric mean.

Table 10.-Summary of abundance, annual survival (%) and standard error estimates for 1992 and 1993 Brood Years of hatchery reared Arctic grayling stocked at age-1 in the lower 144 km of the Chena River, 1993-1997.

Year	$\hat{N}$ [a]	SE [N]	S[b]	SE [S]	n	Length (mm FL) Mean	SD	Min	Max	Growth[c]
1992 Brood (age-5):										
1993[d]	64,936	0	---	---		212	NA	NA	NA	---
1993	33,061	3,190	50.9	0.5		217	21	150	270	5
1994	3,699	307	11.2	0.2		228	18	160	290	11
1995	2,015	283	54.5	1.4		252	16	190	290	24
1996	815	125	40.4	1.7		262	16	190	290	10
1997	388	87	47.6	3.5	39	286	23	242	319	23
1993-1997			0.6[g]	<0.1						

Year	$\hat{N}$ [a]	SE [N]	S[b]	SE [S]	n	Length (mm FL) Mean	SD	Min	Max	Growth[c]
1993 Brood (age-4):										
1994[f]	61,435	0	---	---		208	NA	NA	NA	---
1994	41,928	5,105	68.2[e]	1.0		216	21	198	230	8
1995	2,325	372	5.5	0.2		232	17	200	280	16
1996	573	102	24.6	1.4		246	19	215	293	14
1997	173	48	30.2	3.3	18	270	20	233	301	24
1994-1997			0.3[g]	<0.1						62

[a] $\hat{N}$ is the abundance.

[b] S is the survival rate (%) from the previous year to that year.

[c] Growth is length increase (mm) from previous sample.

[d] 1992 brood stocked 1-11 June.

[e] The survival rate from stocking to sampling, approximately one month.

[f] 1993 Brood stocked 7-30 June.

[g] Survival from stocking to July 1997.

abundance of stock sized fish (150 - 269 mm FL) and recruitment (age class 3). However, these estimates were obtained from the 45 km long Lower Chena section and provide inference on trends applicable to the entire study area. Parameter estimates from the Lower Chena section have paralleled those of the Upper Chena section since 1987 (Figure 9). These suggest that overall abundance in 1997, while greater than the lows estimated in the late 1980's is declining from the high of 45,000 fish estimated in 1995 to likely below 40,000 fish in 1997 (Figure 9). The declining trend of the last two years can be attributed to poor recruitment in 1995 and again in 1997. However apparent these trends are, the low capture rates and probabilities in 1997 produced estimates with low precision. Abundances in 1997 are not significantly different from those estimated since 1991 for stock-sized fish (<270 mm) and 1992 for larger fish (Figures 10 and 11, Table 11).

HATCHERY-REARED FISH

The Arctic grayling stocked into the river in 1993 and 1994 continued to show survival and growth rates that are inferior to those for wild fish. While low initial (60% in the first month) and first year (10%) survival rates may be partly attributable to loss of fish to areas outside the study area (Clark 1995), ensuing rates should be similar to wild fish, provided the remaining fish fully acclimatized. Hatchery fish from both brood years survived at a lower rate in 1997, their third and fourth year after release, than wild fish (30% and 48%, respectively for ages-4 and 5 hatchery fish, Table 10). While size of hatchery fish approximated that of wild age-3 fish at stocking (210 mm versus 198 mm), growth has ranged from 10 to 24 mm per year versus 25 to 32 mm per year for similarly sized wild fish (Table 10). Their abundance in 1997, less than 2% of the population 4 years after stocking, is insignificant and shows that long term enhancement of riverine stocks even under no harvest regulations, can not be accomplished with hatchery-reared fish.

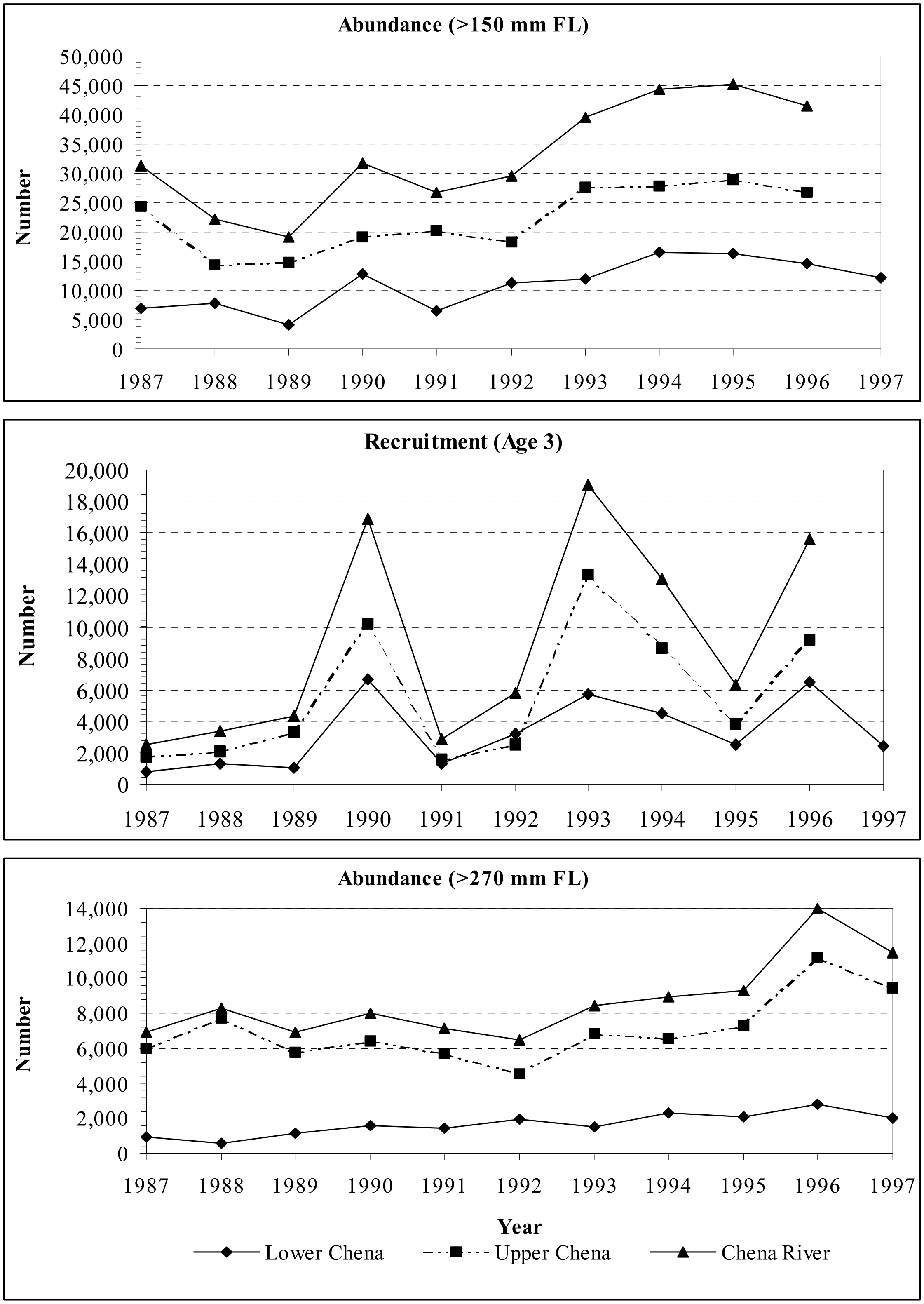


Figure 9.-Estimates of abundance and recruitment for wild Arctic grayling in the Lower and Upper Chena sections and the Chena River study area, 1987-1997.

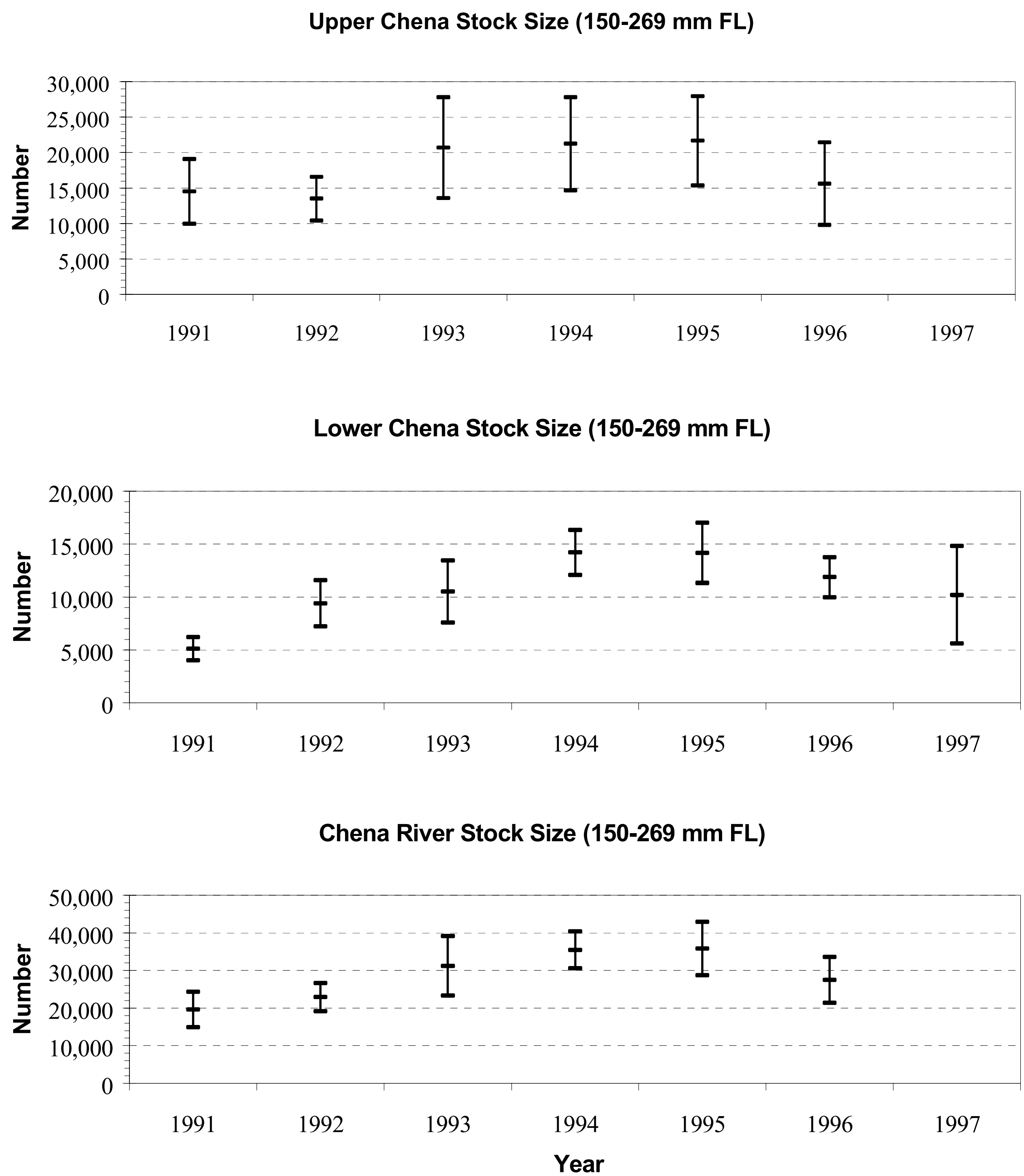


Figure 10.-Abundance and 95% confidence intervals of stock-sized Arctic grayling (150 – 269 mm FL) in the Upper, Lower, and combined study sections of the Chena River, 1991 – 1997.

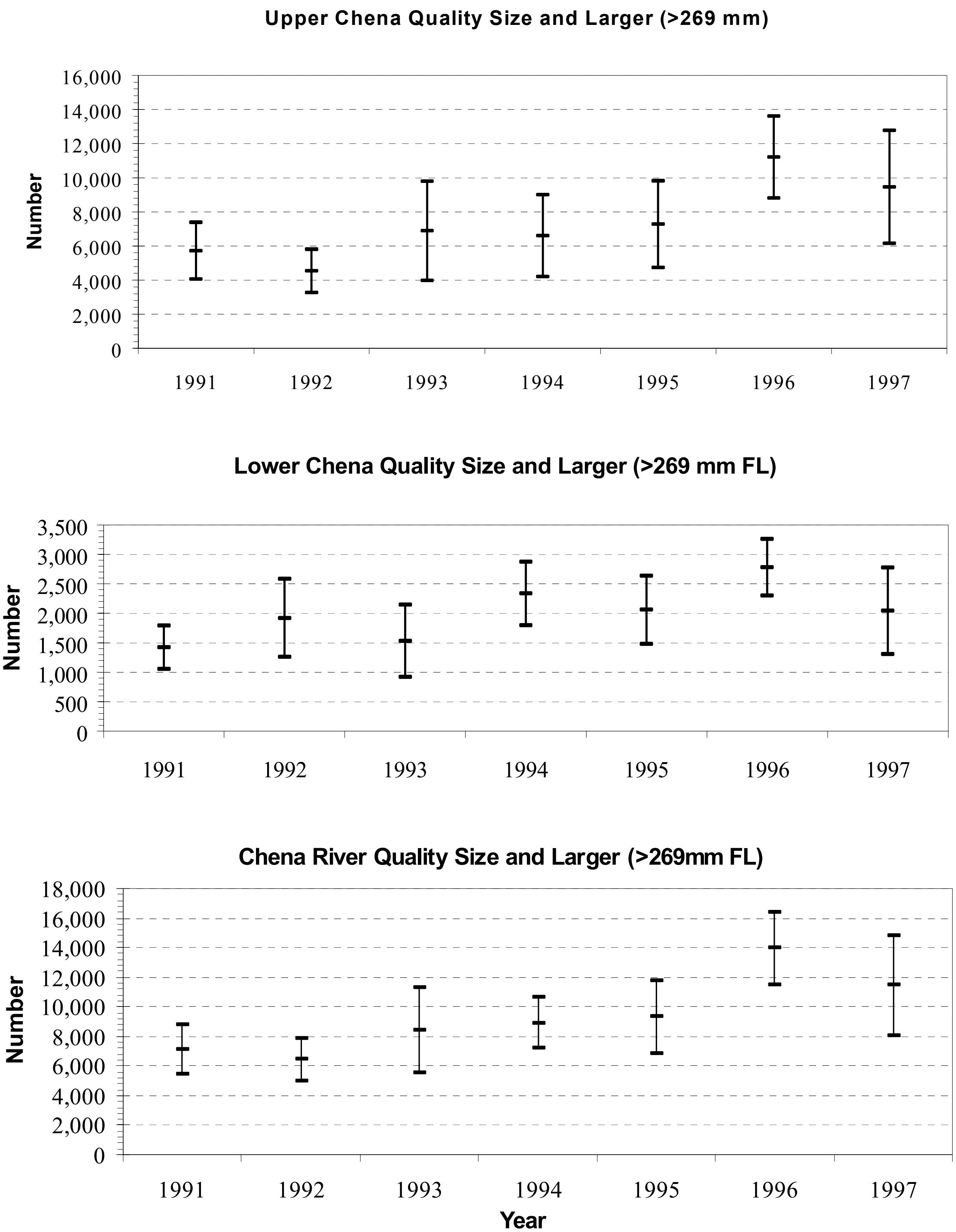


Figure 11.-Abundance and 95% confidence intervals of quality-sized and larger Arctic grayling (≥ 270 mm FL) in the Upper, Lower, and combined study sections of the Chena River, 1991 – 1997.

Table 11.-Abundance, standard errors and 95% Confidence Intervals of stock and quality-sized and larger Arctic grayling (>270 mm FL) in the Upper, Lower, and combined study sections of the Chena River, 1991-1997.

	Stock Size (150 – 269 mm)				Quality and Larger (≥ 269 mm)			
Year	N	SE [N]	-95 CI	+95 CI	N	SE [N]	-95 CI	+95 CI
Lower Chena:					1,426	188	1,058	1,794
1991	5,100	561	4,000	6,200	1,921	338	1,259	2,583
1992	9,394	1,108	7,222	11,566	1,533	311	923	2,143
1993	10,514	1,492	7,590	13,438	2,335	274	1,797	2,873
1994	14,200	1,085	12,073	16,327	2,059	294	1,482	2,636
1995	14,150	1,450	11,308	16,992	2,780	245	2,300	3,260
1996	11,863	962	9,977	13,749	2,044	374	1,310	2,778
1997	10,205	2,348	5,603	14,807				
Upper Chena:								
1991	14,513	2,328	9,950	19,076	5,717	846	4,059	7,375
1992	13,495	1,570	10,418	16,572	4,538	647	3,270	5,806
1993	20,694	3,627	13,585	27,803	6,877	1,486	3,965	9,789
1994	21,239	3,350	14,673	27,805	6,601	1,228	4,194	9,008
1995	21,660	3,209	15,370	27,950	7,276	1,292	4,743	9,809
1996	15,611	2,970	9,790	21,432	11,209	1,229	8,801	13,617
1997	nd[a]	---	---	---	9,458	1,688	6,149	12,767
Chena River:								
1991	19,613	2,395	14,919	24,307	7,143	867	5,444	8,842
1992	22,889	1,921	19,124	26,654	6,459	730	5,029	7,889
1993	31,208	4,028	23,313	39,103	8,410	1,470	5,529	11,291
1994	35,439	2,498	30,543	40,335	8,936	876	7,220	10,652
1995	35,810	3,636	28,683	42,937	9,335	1,273	6,840	11,830
1996	27,474	3,121	21,357	33,591	13,989	1,252	11,536	16,442
1997	nd[a]	---	---	---	11,502	1,729	8,112	14,892

[a] nd = no data. Abundance of stock-sized fish could not be estimated in the Upper Chena section.

CHAPTER II: RADIOTELEMETRY

INTRODUCTION

Seasonal migrations and stratified summer populations are common in riverine Arctic grayling populations (Tack 1980, Northcote 1995). Migrations occur in fall and spring and are minimal in summer and winter. Migration can be simple, from point A to point B within a reach or drainage, or complex involving many reaches of one or more drainages. This movement of the population, whether in total or stratified by age and length, into and out of particular river reaches can have significant implications in relation to design of research and assessment programs as well as angler opportunity. Estimates of abundance, mortality (natural and fishing), recruitment, and sustainable yield of a population from an assessment program constrained in time and place may be biased if different segments and/or proportions of a population are in the assessed area of a river for variable periods of time. Recent studies of Arctic grayling in the lower Goodpaster River (Ridder, in prep.) has shown that estimates of population abundance and composition can be significantly different depending on time of sampling. Abundance of adult sized fish (>269 mm FL) in the lower 53 km of the Goodpaster River was >85% larger during their spawning period in May of 1995 and 1996 than during their summer feeding period in August 1994 (N = 10,700 and 17,000 versus N = 1,500). These adult sized fish contributed >75% of the estimated population in May while they were only 20% of the population in August. After their May spawning, these fish dispersed to upper reaches of the Goodpaster River as well as emigrating to the Delta and Richardson Clearwater rivers. Emigrating fish, estimated at 7%-11% of the estimated abundance, came primarily from the lower 29 km of the Goodpaster River.

The present stock assessment program in the Chena River was implemented in 1987 in the lower 144 km to allow researchers and managers to assess the population's response to conservative management actions. The program has provided parameter estimates that have described annual stock status, documented population trends and been used in population models. However, biologically, the program assesses only a component of the population specific to time (July) and place. The assessed area comprises approximately 80% of the 183 km long accessible portion of the drainage (from Monument Creek by Chena Hot Springs Resort to the mouth) but only 38% of the drainage's length (approximately 470 km of major tributaries and mainstem).

RESEARCH OBJECTIVES

This study examined movements of radio-implanted adult Chena River Arctic grayling residing outside the present assessment area from August of 1997 through July of 1998 using radiotelemetry techniques. The study had the following assumptions:

1. the summer feeding period extends from 1 July through 15 August;
2. the distribution of adult Arctic grayling during the summer feeding period is static;
3. small adult fish (<330 mm FL) behave similarly to the larger adults which will carry the radio transmitters;
4. spawning and overwintering areas are different from summer feeding areas; and,
5. the rate of tag failure plus total mortality of implanted fish does not exceed 50% (a failure/mortality rate of 47% was found in the 1995 radiotelemetry project in the Delta Clearwater River).

The goal of the study was to estimate the proportion of these adults that seasonally inhabit the assessed area, for how long and for what purposes.

Specific objectives were to:

1. estimate the proportion of large ($\geq$ 330 mm FL) adult Arctic grayling that are present in five areas of the upper Chena River (East, West, South and North forks and the 29 km of the mainstem below the North and West forks) in early August which enter the assessed area in the lower 144 km of the Chena River at any time during open water (May - October); and,
2. locate overwintering and spawning areas of large Arctic grayling implanted with radio transmitters that were released in the upper Chena River drainage in August.

In addition to these objectives, estimates of homing to summer feeding areas and distances moved, spring temperature gradients and size compositions were described to help improve our knowledge of the behavior and distribution of adult grayling in the Chena River. Knowing the behavior and distribution of adult Arctic grayling will enhance our understanding and use of the present Chena database as well as providing direction for new research and management approaches.

METHODS

Radiotelemetry was used to track 54 Arctic grayling that were implanted with radio transmitters between 6 - 20 August 1997 in the North, West, East (Middle) and South forks and the upper 12 km of the mainstem (Figure 12). Attempts were made to distribute tags evenly along each tributary but were thwarted in places by a combination of accessibility, and availability of transportation. Access into the mostly inaccessible area was by helicopter, boat, truck, foot, and ATV. Four crews of two people each captured fish with rod and reel equipped with a curly tailed jig.

The radio transmitters each had a unique frequency (Appendix C1) and were manufactured by Lotek Engineering Inc (Model MBFT-5) and were 49 mm long and 11 mm in diameter, had an air weight of 8.9 g, and a plastic coated flexible whip antenna 31 mm long. The transmitters produced 30 beeps per minute with a guaranteed life of 344 days, suggesting that operation would extend at least to 16 through 30 July, 1998.

The 2% rule (Winter 1983: transmitter weight not to exceed 2% of the fish's weight in air which in this case was 445 g) was used as a guide in selecting fish for surgery. All captured grayling were measured to the nearest 1 mm fork length (FL). Based on the length weight relationship found for Delta Clearwater River Arctic grayling ($\log W = -4.997 + 3.035 * \log L$; unpublished data), the 2% rule dictated fish with a minimum length of 330 mm FL. Fish greater than 330 mm FL, preferably males (see below), were then selected for surgery and were weighed to the nearest gram. Fish implanted with radio tags were also tagged with Floy FD67 anchor tags.

Four people performed the surgeries and all had prior experience with implantation. Fish were anesthetized with MS-222, and transmitters were placed in the coelomic cavity following the surgical procedures described by West et al. (1992). An exception was that 4 stitches were used to close the 20-30 mm long incisions and these were followed by an application of "Vetbond", a cyanoacrylate tissue adhesive. Surgery times averaged less than 6 minutes. After surgery, each

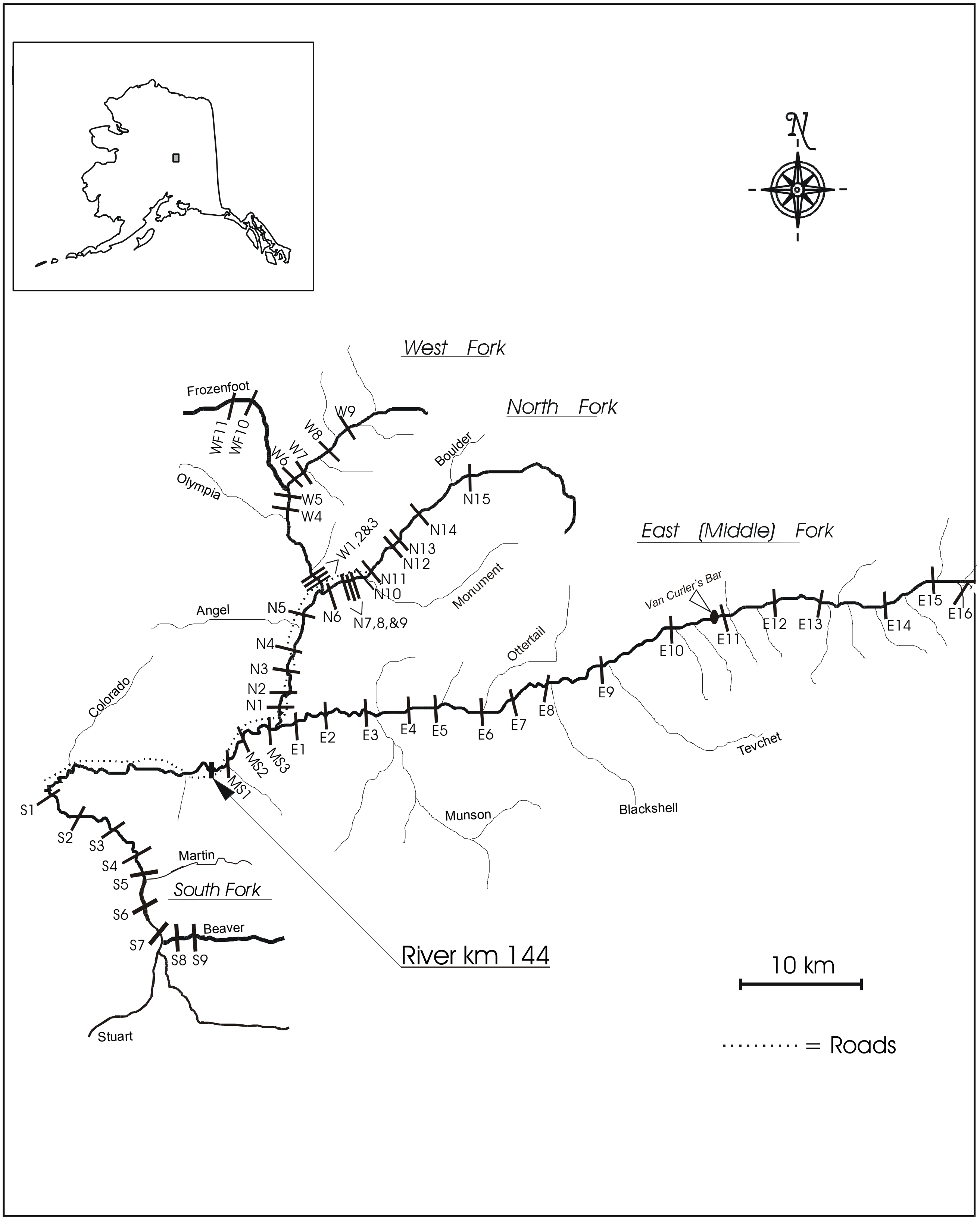


Figure 12.-Release locations of 54 Arctic grayling implanted with radio transmitters, Chena River, August 1997.

fish was allowed to fully recover from the anesthetic in a tub of fresh water prior to release. No mortalities occurred during surgery, the recovery period, or for a short time after release.

TRACKING

Locations of tagged Arctic grayling were determined in nine, one to two day flights from September 1997 though July 1998 from three types of aircraft (Table 12) and antennae configurations. The R22 helicopter employed a single 'H' antennae orientated forward, the Piper PA 18 used two 'H' antennae oriented to the sides, the Cessna 185 used two 'H' antennae oriented forward. All aircraft were equipped with up to two Telonics TR-2 receivers each coupled with a TS-1 scanner. Two observers each monitored 24 frequencies on the receivers during the first day of a flight while usually one observer monitored the 'leftover' frequencies on the second day of a flight (Table 12). Five different personnel acted as observers: two observers were neophytes in radio tracking and were involved with three flights while three observers were experienced and flew on five flights. Flights were directly over stream courses as much as practical at 180 m- 360 m above ground level and 128 – 176 mi/h for the Cessna 185, 32 - 80 km/h for the R22, and 96 - 128 km/h for the PA-18. Flights covered the same search area at least twice (upstream then downstream) with the slower craft and four times with the Cessna. The search area extended from the mouth of the mainstem to about 5 km above the uppermost point of each tributary where fish were released. This area was common to all but the 9 September and 29 June flights. The 9 September flight covered only the road accessible portion of the drainage, from the mouth to Chena Hot Springs Resort, and the 29 June flight sought only specific tags for ground truthing. The Little Chena River was included in the 23 February through 20 May flights. The 23 February flight also flew 16 km of the Tanana River downstream of the Chena River. The flights from 29 April on included some third order tributaries, named later, whose lengths suggested possible spawning areas.

Location of a transmitter was determined by monitoring its pulse intensity for the 'null point', which is a noticeable decline in pulse intensity when passing directly over the transmitter. The location of the null point was then recorded with a GPS (global positioning system) receiver as latitude and longitude coordinates on a field form. General location descriptions in estimated river kilometer were also noted. In most instances, two or more passes along a stream reach were necessary to determine the location of a specific transmitter. For a few frequencies among the flights, pulse intensity was erratic and dependent on the direction of the flight or it was weak with ambiguous null points. In these situations, determination of location was somewhat arbitrary. The coordinates for each transmitter were then transferred to a computer spreadsheet where straight-line distances (SLD) were calculated as:

$$SLD = \sqrt{[(lat_i - lat_{i-1}) * 111km]^2} + (long_i - long_{i-1})^2 \qquad (15)$$

where:

lat_i	= the latitude of the *ith* location in degrees;
$long_i$	= the longitude of the *ith* location in degrees;
11 km	= the distance of one degree latitude; and,
46 km	= the distance of one degree longitude near the 65th parallel.

At the conclusion of the experiment, those coordinates associated with fish presumed alive over the majority of flights were plotted on United States Geological Survey topographical maps

Table 12.-Survey schedules, hours flown and tracking results for aerial surveys of radio-tagged Arctic grayling in the Chena River drainage, 1997 to 1998.

					Number of tags		
Date	Aircraft	#Trackers	Area[a]	Hours	Searched	Found	Not Found
9/9/97	R22	1	MS, NF to Resort	2.3	54	17	37
10/30/97	Cessna 185	2	All	4.3	54	45	9
10/31/97	Cessna 185	1	All	2.5	9	3	6
2/23/98	Super Cub	1	All+Tanana	5.8	54	48	6
4/29/98	Cessna 185	2	All	4.5	54	31	23
4/30/98	Cessna 185	1	All+LCR	4.2	23	17	6
5/20/98	Cessna 185	2	All+tribs	5.0	54	31	23
5/21/98	Cessna 185	2	All	4.5	23	16	7
6/1/98	Cessna 185	2	All+tribs	4.5	54	43	11
6/2/98	Cessna 185	1	All	2.6	11	4	7
6/16/98	Cessna 185	2	All+tribs	4.2	53	40	13
6/17/98	Cessna 185	1	All	3.1	13	8	5
6/29/98	R22	1	Selective	3.0	9	8	1
7/29/98	Cessna 185	1	All	4.4	27	24	3

[a] Area denotes area searched: All = Chena River and all forks; MS = mainstem; NF = North Fork; LCR = Little Chena River; tribs = selected tributaries (see text); Selective = seclected areas to ground truth for specific radio tags.

(1:63,360 scale) (Appendix C2). One-mile increments were also plotted on the maps with the aid of a planimeter and plotted locations were estimated to the tenth of a mile to estimate distances moved. These miles were transformed into kilometers for this report.

A remote tracking station was used to detect, identify, and record when tagged fish moved into or out of the assessed area. The station was comprised of integrated components: a marine deep cycle 12 v battery, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, and two 5 element Yagi antennae. The station was placed approximately at river kilometer 143 with an elevated (2.5 m) Yagi antenna pointed upstream and one downstream. The station was programmed to scan through the 54 frequencies at 2.5 s intervals on each antenna for total scan time of 4.5 min. With this long a scan time, it was possible for fish to pass undetected if more than two fish were together and speed was equal to flow. This situation was plausible but was considered a low probability. However, it was unavoidable due to the type of tag and its low pulse rate.

DETERMINATIONS

The location coordinates were inaccurate since some plots showed fish up to 400 m off the stream. Five radio tags were found during the 29 June ground truthing flight. Locations of radio-tagged fish determined from the air were from 0 km to 0.9 km from those determined on the ground.

	No. of times	Distance (km) moved between tracking flights		
Tag #	Located	Minimum	Maximum	Average
EF1	6	0.1	0.6	0.4
MS1	7	0.0	0.9	0.3
EF4	7	0.1	0.6	0.4
EF7	6	0.2	0.7	0.4
SF2	5	0.2	0.4	0.3

Evenson (1993) determined that actual river locations of radio-implanted burbot were within 0.5 km of locations determined from the air using the same equipment as this study. Given this accuracy, the estimated location of a fish may be off up to 1.3 km in any tracking event. In this study, movements of fish between trackings were deemed to not have occurred if SLD's were less than 1.3 km with one exception: fish SF4. Located first on the 30 October survey, SF4 had moved 41 km downstream of its release site and 1 km up into the Little Chena River with its subsequent five locations all having SLD's of less than 1.3 km (Appendix C3). However, for its' last three locations, the fish had dropped out of the Little Chena, moved upstream 2 km and remained in the general vicinity. Fish SF4 was considered to have moved in this study.

Mortality

Determinations of mortality are necessary in qualifying the tracking results. This study addressed mortality as inferences from tracking results. If fish did not move between three or more trackings and especially if these trackings spanned times of movement i.e. fall and spring, then the fish was presumed dead or had shed the tag (Appendix C2). An Arctic grayling determined dead at the end of the study was removed from the analysis beginning with the first tacking flight in which no movement was determined.

Overwintering
Overwintering locations were determined with one February flight as suggested by Lubinski (1995).

Spawning
Spawning activity and areas were inferred from a combination of spring ice break-up conditions, water temperatures, and sampling of fish for sex and maturity along the lower 144 km of the mainstem (two sites in North Fork and one site in the East Fork). The mainstem sampling used one electrofishing boat and crew as described in Chapter 1. The boat actively searched for fish during one complete downstream pass. Sampling occurred in a stepwise fashion of approximately 24 km 'steps' starting in the lower river. The sampling in the forks was with rod, reel, and curly tailed jig. Tack (1980) stated that Arctic grayling commence spawning at 4°C soon after ice-out. Remote water temperature loggers were set out 29 April at river kilometer 8, river kilometer 72, and river kilometer 146 and 'spot' temperatures were recorded in the East and North forks with a mercury thermometer. Beauchamp (1990) and Ridder (1989 and *In prep*) noted that spawning commenced rapidly with warming temperatures, males spent more time on spawning grounds than females, and duration of spawning activity ranged from 6 to 16 days. Three survey flights to locate spawning areas began at ice break-up and were planned to repeat every 7 days.

Sex
Either one or more of the following determined sex: sexual dimorphism, the presence of ovaries during surgery, the extrusion of eggs or milt and extended abdomens during spawning. Dimorphism is evident in differences in length of the dorsal fin (in fish greater than 300 mm FL, the male dorsal fin usually extends to the adipose fin whereas the female dorsal fin is noticeably shorter; Wojcik 1955). During the spawning period, fish with distinctly extended abdomens, short fins and no sex products were classed as 'green' females.

All data pertaining to age, length, sex, tag numbers, colors, and losses (from previous studies), release location, transmitter frequencies, and finclips were recorded on mark sense forms and transformed into an electronic (ASCII) data file, U00101aa.dta. Latitude and longitude coordinates of radio tags found during aerial surveys were transcribed to a spreadsheet, Lat_Long.xls. These data files are archived in file U0010aa.zip at the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

DEFINITIONS AND NOMENCLATURE
Distances in this report are presented as river kilometers upstream from the tributary's or fork's confluence and are followed with the acronym of the tributary. River kilometer 5 NF is the fifth km of the North Fork upstream of its confluence with the East Fork; river kilometer 10 WF is the tenth km West Fork upstream of its confluence with the North Fork.

Radio-implanted Arctic grayling are identified by the acronym of the fork in which they were caught followed by their position in the tributary i.e. WF1 is the first fish tagged in the West Fork upstream of its confluence, WF2 is the second fish etc.

The assessed area of the mainstem, hereafter referred to as MSA, is the reach from river kilometer 0 MS (mainstem) to river kilometer 144 MS. Other significant landmarks in this report and their locations (hereafter referred to by their acronyms) in the drainage are:

Landmark	River Kilometer	Location
Upper limit of mainstem, confluence of the East and North forks	156	Main Stem
South Fork (SF) confluence with MS	125	Main Stem
Moose Creek Dam	72	Main Stem
Little Chena River	39	Main Stem
Badger Slough	35	Main Stem
Beaver Creek confluence with SF	36	South Fork
West Fork (WF) confluence with North Fork (NF)	18	North Fork
Monument Creek confluence with NF	24	North Fork
Chena Hot Springs Resort	3	Monument Creek (NFM)
Frozenfoot Creek confluence with WF	14	West Fork
Munson Creek confluence with East Fork (EF)	14	East Fork
Van Curler's Bar	57	East Fork

RESULTS

Radio tags were surgically implanted in 54 Arctic grayling in five areas of the upper Chena River drainage over a 15-day period from 6 to 20 August 1997 (Figure 12; Appendix C1). Thirty-five fish in the uppermost reaches of the North, East, and West forks were implanted in the first 6 days under the assumption that these would be the first to begin fall movements. Two tributaries to these forks were included due their overall size being similar to, or larger than, the reaches upstream of them. Three fish were implanted in Beaver Creek of the South Fork (SF) and two fish were implanted in Frozenfoot Creek of the West Fork (WF). The planned and actual distribution of tags and each area's length and sampled reach were:

			Number tags	
Location	Length (km)	Reach (km)	Planned	Actual
North Fork	56	0 – 42	9	15
East Fork	99	0 – 86	17	16
South Fork	96	0 – 46	16	9
West Fork	56	0 – 28	9	11
Mainstem	12	144 – 156	2	3
Totals	319	214	54	54

The study planned to distribute the tags in proportion to the tributaries' estimated length. Usually, fish suitable for surgery were quickly caught at each site despite low densities in the uppermost reaches. However, the presence of large beaver dams in the upper North, South and

West Forks appeared to affect fish presence. No fish were caught or seen above large beaver dams at 45 km NF or 28 km WF. Only small fish were caught above dams at 44 km NF and 86 km SF. This affected the even distribution of radio tags in each area as ability to access areas blocked by dams was decreased. In the NF and WF, releases of radio-implanted fish were thus concentrated in the lower reaches (Figure 12). Distribution of radio tags in the SF was further constrained by the US military's Stuart Creek Impact Range that covered approximately 50 km of its length.

Lengths and weights of the 54 radio-implanted fish ranged from 345 mm to 420 mm FL and 395 g to 865 g (Appendix C1). Fish from the East Fork were larger than the other areas:

	Length (mm FL)				Weight (g)			
Area	Min	Max	Ave	SD	Min	Max	Ave	SD
NF	345	419	375	20	395	797	552	110
EF	354	420	386	23	435	865	647	149
SF	355	387	372	12	435	605	497	57
WF	352	393	371	14	435	865	556	99
MSA	370	378	375	4	526	552	536	14

Forty-seven fish were males, six fish were females, and one fish was of unknown sex. Four fish did not meet the 2% rule: fish EF3, NF15, SF8, and WF8 (Appendix C1). After the final tracking, these four fish were determined dead prior to the first flight (Appendix C2).

Eight surveys and one ground truthing survey were flown between 9 September 1997 and 28 July 1998 to locate radio tags (Table 12). The first survey, 9 September, was limited to just the road accessible portion of the drainage to determine entry of radio tags into the MSA. Five of the seven full surveys took 2 days to complete mostly due to the poor ability on the first day to detect tags with high air speeds even with two observers each scanning only half the frequencies. Each survey flight searched for all tags except the last two. The 16 June flight searched for only 53 tags after an angler reported finding NF1 on 5 June. The 29 July flight searched for 27 tags after culling out dead fish. Fifty-one of the 54 tags were located at least three times while one tag was never located (Appendix C2). Mortality of radio-implanted fish was highest prior to the February flight. Thirty fish remained alive for the February flight and 23 remained alive through the duration of the study:

Date	Dead	Cum Dead	Alive
08/20/97	0	0	54
09/09/97	6	6	48
10/30/97	8	14	40
02/23/98	10	24	30
04/29/98	3	27	27
05/20/98	1	28	26
06/01/98	0	28	26
06/16/98	2	30	24
07/29/98	1	31	23

RESIDENCY

The proportion of radio-tagged fish that are vulnerable to the fishery in the MSA is dependent not only on a tagged fish entering the area but also on the length of time spent in the area. This study failed to accurately estimate residency time in the MSA due to the unreliability of the remote tracking station in detecting tags. On each scan, the station would detect at least one 'hit' on each frequency and produced erratic and unrealistic intensity readings on those frequencies it fixed on. The station was operational from 22 August through 11 November. Of the seven tagged fish that could be said to have passed the station by 30 October, the aerial survey on the same day located four fish well upstream of the station and one fish that had yet to leave the SF, 18 km below the station. A boat survey on 21 August from river kilometer 144 MS to river kilometer 116 MS detected 19 tags while the 9 September survey detected only three tags in the reach. The problem may lie in interference and echoes on ground level surveys produced by the high hills surrounding the narrow valley in the area of the station and survey.

The best estimate on residency of tagged fish in the MSA is the aerial survey results themselves. Residency ran from September to June and ranged from 8% to 35% (SE = 5% and 10% respectively; Table 13) of all live, tagged fish. The February to May period had the highest percentage of tags, 29% to 35% (SE = 9% and 10%, respectively; Table 13).

OVERWINTERING

The 23 February survey located 29 of the 30 tags determined to be in live fish (Appendix C3) with the majority (34%, SE = 10%; Table 14) overwintering in the MSA, although all the forks were used (Figure 13). Movements to overwintering areas were all downstream from release sites and ranged from less than 1 km to 104 km (Appendix C4). Concentrations of four or more fish were found in three areas: the upper 6 km of the MSA, at 16 km NF above Angel Creek, and at 64 km EF near Wolf Creek. These three areas were characterized by heavy aufeis accumulations, especially the NF site. A similar aufeis field was located in the WF where two fish overwintered.

SPAWNING

Break-up of the Chena River was unusual in 1997 due to its early timing and a prolonged, cold spring, shallow snow pack, and low water levels from a two-year drought. It began around 12 April in the lower river with scattered open leads in the ice as far up as 117 km MS at the Rosehip Campground. Anglers first reported catching Arctic grayling on 21 April at Peede Road near 35 km MS, while shore bound ice was still prominent along the lower river and in a few places reached bank to bank. Water temperatures at 14 km MS were 0.5 °C and 1.6 °C on 16 April and 22 April. The river below 144 km MS was not open for boat travel until 27 April. On this date, anglers reported large Arctic grayling moving into Badger Slough at river kilometer 35. Water temperatures initiating spawning, 4 °C, were first reached in the lower 72 km of mainstem below Moose Creek Dam on 28 April and 6 days later at the first bridge at river kilometer 144 MS (Figure 14). Above the confluence of the West Fork, spawning temperatures in the North Fork lagged behind the lower river with temperatures reading below 1°C on 24 April and 9 May.

Table 13.-Numbers and proportions of live radio-tagged Arctic grayling located in six areas from eight aerial surveys of the Chena River drainage, 1997 and 1998. The numbers of fish initially released by area is in the shaded area.

Survey		Mainstem Assessed Area			Mainstem Above Assessed			East Fork			North Fork			West Fork			South Fork		
Date	n	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE	n	p	SE
Releases	54	0			3			16			15			11			9		
9/9/97	47	6	0.13	0.05	2	0.04	0.03	ns[a]	---	---	3	0.06	0.04	1	0.02	0.02	ns	---	---
10/30/97	36	5	0.14	0.06	6	0.17	0.06	6	0.17	0.06	9	0.25	0.07	5	0.14	0.06	5	0.14	0.06
2/23/98	29	10	0.34	0.10	3	0.10	0.06	7	0.24	0.08	6	0.21	0.08	2	0.07	0.05	1	0.03	0.03
4/29/98	26	9	0.35	0.10	2	0.08	0.06	6	0.23	0.08	6	0.23	0.08	2	0.08	0.05	1	0.04	0.04
5/20/98	24	7	0.29	0.09	1	0.04	0.04	7	0.29	0.09	6	0.25	0.09	2	0.08	0.06	1	0.04	0.04
6/1/98	25	2	0.08	0.05	2	0.08	0.06	6	0.24	0.09	11	0.44	0.10	2	0.08	0.06	2	0.08	0.06
6/16/98	24	2	0.08	0.06	1	0.04	0.04	5	0.21	0.08	8	0.33	0.10	5	0.21	0.08	3	0.13	0.07
7/29/98	23	0	0.00	0.00	2	0.09	0.06	5	0.22	0.09	8	0.35	0.10	5	0.22	0.09	3	0.13	0.07

[a] ns = area not searched.

Table 14.-Number and proportion of live radio-tagged Arctic grayling located in six areas during overwintering and spawning in the Chena River drainage in 1998.

	Overwintering			Spawning		
Location	n	p	SE	n	p	SE
Mainstem Assessed	10	0.34	0.10	10	0.37	0.09
Mainstem Other	3	0.10	0.06	1	0.04	0.04
South Fork	1	0.03	0.03	1	0.04	0.04
East Fork	7	0.24	0.08	7[a]	0.26	0.09
North Fork	6	0.21	0.08	6	0.22	0.08
West Fork	2	0.07	0.05	2[b]	0.07	0.05
Totals	29	1.00	---	27	1.00	---

[a] One fish in Munson Creek.

[b] Both fish in Frozenfoot Creek.

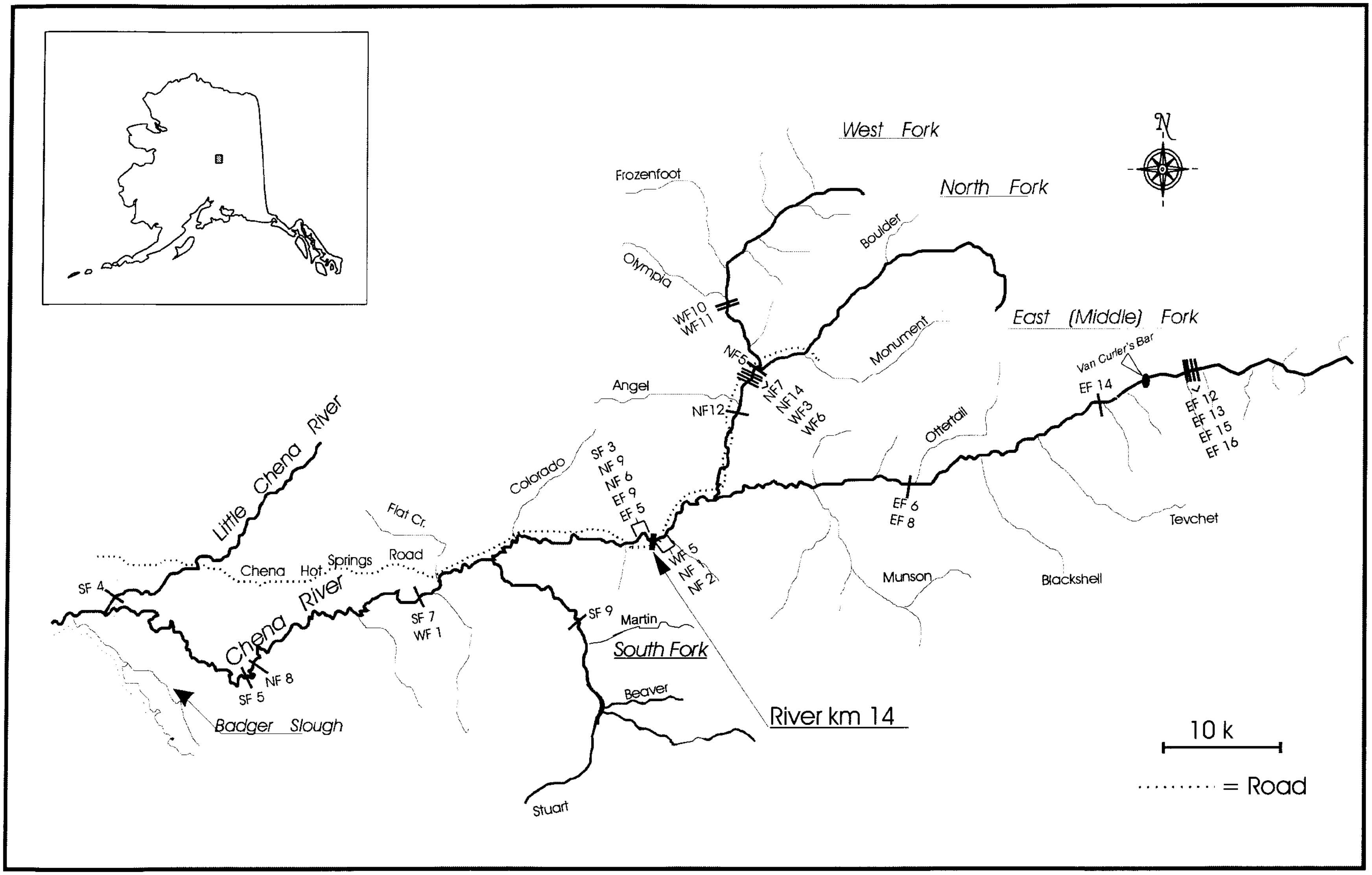


Figure 13.-Overwintering locations of 29 Arctic grayling implanted with radio transmitters, Chena River, February 1998.

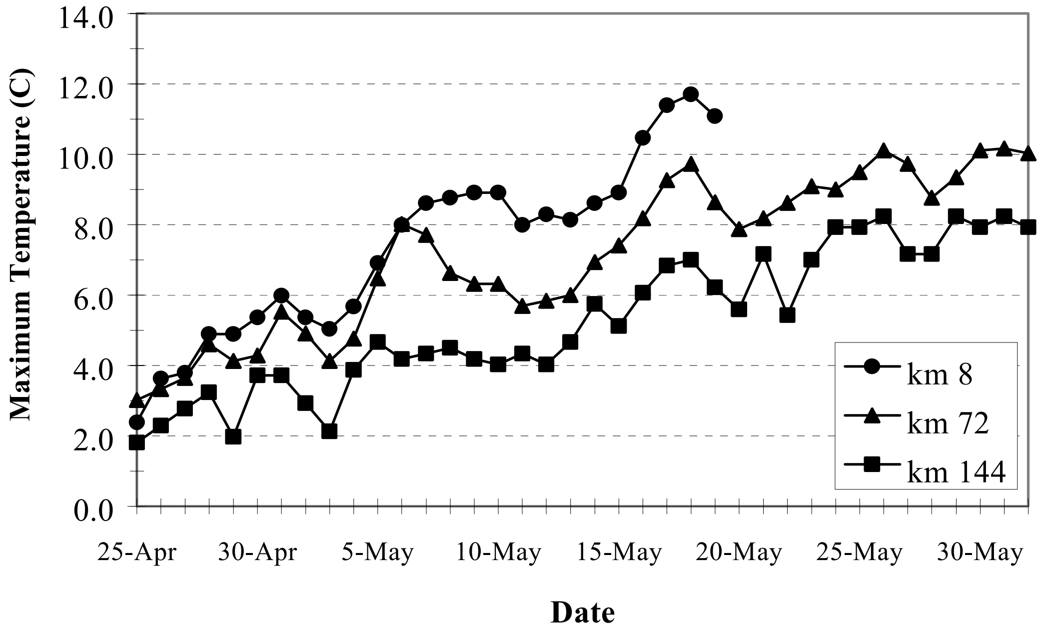


Figure 14.-Daily maximum water temperatures (C°) at river kilometers 8, 72, and 144 of the Chena River, 25 April through 1 June 1988.

The North Fork first reached 4°C some time before 22 May (5.3°C) which coincides with the first reported angler catches. The temperature on the same day in Monument Creek, 6 km upstream, was 4.1°C. The warming of the East Fork at Van Curler's Bar, 57 km upstream of the North Fork, was likely still later with 2.2°C on 20 May, 8.5°C on 1 June, 6.5°C on 2 June, and 8.7°C on 16 June. Based on a temperature range of 4°C to 8°C, the majority of spawning likely occurred between 28 April and 1 June and progressed from downstream to upstream.

In addition to the temperature data, Arctic grayling samples from 29 April through 16 June found Arctic grayling in spawning condition in the MSA and the North and East forks, and indicated that the spawning period again ranged from 29 April to 1 June. From 29 April to 9 May, 2,631 Arctic grayling were sampled along the 138 km of the lower 144 km assessed area (Appendix C5). Catches included 1,908 adult fish, 1,282 males and 626 females. The majority of adults were caught in the vicinity of riffle areas throughout the reach. During the sampling, nearly all males gave milt however only 23% of the females were classified as ripe or spent with the rest, green. Ripeness was least over the first two days (lower 40 km) and the last day (the 16 km above the South Fork). Catches also included three radio-tagged fish and three Arctic grayling, tagged with anchor tags in the East Fork in August 1992. One radio-tagged fish, WF2, was caught off Badger Slough while the other two, NF8 and SF5, were caught within the 18 km above Moose Creek Dam (Appendix C6). The three anchor-tagged EF fish were released in 1992 between 30 km and 51 km EF and all were caught in the vicinity of Badger Slough between river kilometers 30 and 43. Two areas of the North Fork, where radio tags were located on 20 - 21 May, were sampled with hook and line on 22 May. In Monument Creek, 11 Arctic grayling, 315 mm to 400 mm FL, were caught, all adults. Three of the four females were ripe and one spawned out. Six of the seven males gave milt. Five adults were caught at river kilometer 20 NF, three females and 2 males. One of the females was spent and one was ripe and four males were observed distributed across a riffle. Hook and line samples were collected in the East Fork on 2 June and 16 June at Van Curler's Bar at river kilometer 57. Ten adult Arctic grayling, 340 mm to 425 mm FL, were sampled on 1 June of which two were spawned out females. Of the eight males, five males gave milt. On 16 June, eight Arctic grayling ranging from 340 mm to 415 mm FL were sampled. Two were classified as males; one gave a 'little' milt. The one fish that didn't give milt was a radio-tagged Arctic grayling, EF14.

Three surveys were flown during the spawning period, 29 April and 1 June (Table 12). The surveys located all 27 fish alive during this period at least once and 24 fish were located on all three flights (Appendix C3). From the above temperature and sampling data, spawning occurred at different times along the drainage's length so spawning area determinations were made from fish located on different flights depending on their locations in the drainage (Appendix C3 and C6). Tracking histories of live fish overwintering under the aufeis fields in the East and North forks illustrate this approach as they had not moved from 30 October through 29 April (Appendix C3).

The 27 fish were found nearly evenly spread along 280 km of the drainage from Badger Slough throughout the mainstem, all four forks and two tributaries as far upstream as Frozenfoot Creek and 62 km EF (Figure 15). The only concentration, four fish, was within 2 km of the mouth of the South Fork. Thirty-seven percent of the fish likely spawned in the assessed area (SE = 9%; Table 14). The percentage of fish found in the East and North forks were similar, 26% and 22%, respectively (SE = 9% and 8%, respectively). The South and West forks each held less than 10% of the fish. Nineteen of the 27 fish were initially tagged in areas away from the road accessible

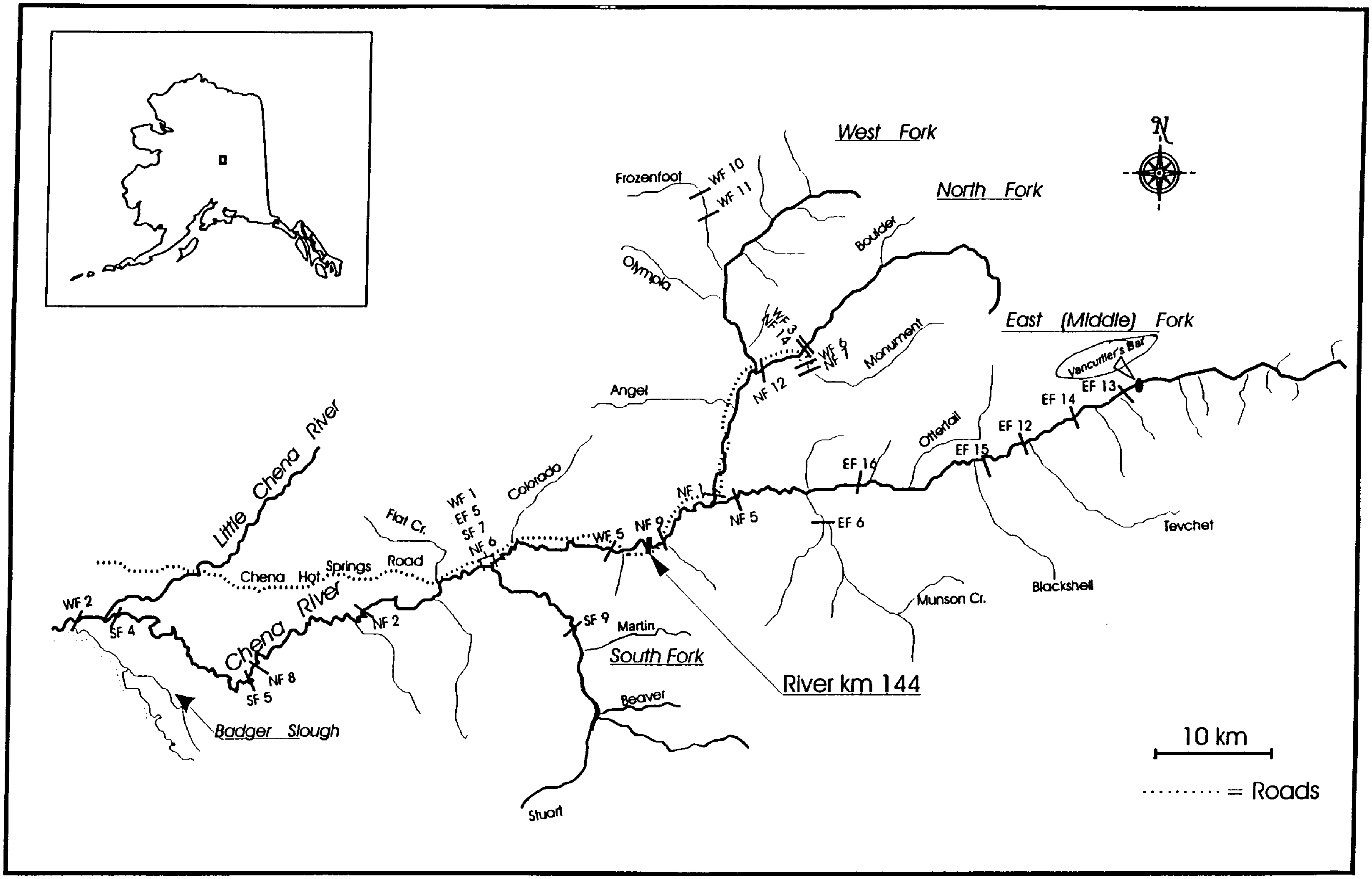


Figure 15.-Spawning locations of 27 Arctic grayling implanted with radio transmitters, Chena River, 29 April through 1 June 1998

portion of the drainage. At spawning, nine of these 19 fish, or 47%, were spawning adjacent to the road accessible reach.

There was some disparity among the choice of spawning areas depending on where the fish was released. The majority of East Fork fish preferred to remain in the East Fork whereas the majority of South and West Fork fish moved elsewhere, predominantly into the assessed area (Table 15). North and West Fork fish were the most dispersed moving to five and four locations, respectively.

HOMING

Twenty-three live radio-tagged fish were located on the last survey of 28 July 1998, 11 months after implant surgery, and all but three fish were in the area of their release (Appendix C7). Thirty-nine percent of the fish were within 1 km of their release sites and 49% were within 2 km (Table 16). Three fish, 13%, were 10 or more km away. The majority of fish were downstream of release sites with only three fish found above the sites. None of the 23 live radio-tagged fish were located in the mainstem below river kilometer 144 in the MSA.

DISCUSSION

Most radio tagged fish moved downstream to overwinter, with many moving into the MSA by February. These results are similar to earlier radio telemetry studies (Tack 1980), Holmes et al. (1986) and Merritt (*Unpublished*) which found that radio tagged Arctic grayling remained in the Chena River over winter, with many fish moving downstream during the winter. An important finding is that most radio tagged fish spawned within 25 km of their overwintering site. All surviving radio tagged fish returned by mid June 1998 to within a few kilometers of where they had been initially captured in August 1997. Thus, the fish radio tagged outside of the MSA used the MSA for overwintering and spawning, but exited the MSA prior to the traditional times of stock assessment. This last finding shows that regularly scheduled mark-recapture experiments should produce unbiased estimates of abundance of fish in the MSA during July. The estimate of abundance in the MSA is less than the actual abundance of fish in the Chena River. Fish from the South and West Forks were twice as likely to be in the MSA during spawning than fish from the East or North forks (Table 15). Fish from the upper reaches of the study area generally tended to move the least and moved downstream from overwintering areas to spawning areas. Those fish from the lower reaches tended to move the farthest and moved downstream to spawning areas. A logical extension of this study would be to radio tag fish within the MSA to determine to what extent these fish travel outside of the MSA.

There is no reason to believe that behavior of radio-implanted Arctic grayling was not similar to Arctic grayling not implanted with radio tags. Intuitively, the six to ten month interval between surgery and the overwintering and spawning surveys was sufficient for surviving fish to heal and overcome any behavior modification due to the surgical procedure. Electrofishing of the assessed area during the spawning period found adult Arctic grayling throughout the reach in much greater numbers and in a wider distribution than July sampling (Figure 16; Appendix C8). The four radio-implanted fish recaptured in this study were all healthy with near indistinguishable incisions. However, normal behavior cannot be assumed for shorter time intervals and likely biased residency estimates in the MSA for September and October. From mortality determinations, the greatest mortality or tag shedding occurred prior to the February flight and was minimal from then to the last survey in July. The six fish that were found in the

Table 15.-Spawning distributions of 26 radio-tagged Arctic grayling released in four tributaries in August 1997. In parentheses are the numbers of radio tags released in each area.

Spawning Areas	Release Areas				Total
	North Fork (15)	East Fork (16)	South Fork (9)	West Fork (11)	
North Fork	3	0	0	1	4
Monument Cr. (NF)	1	0	0	1	2
East Fork	1	5	0	0	6
Munson Cr. (EF)	0	1	0	0	1
South Fork	0	0	1	0	1
Frozenfoot Cr. (WF)	0	0	0	2	2
Mainstem	1	0	0	0	1
Mainstem Assessed	3	1	3	3	10
Total	9	7	4	7	27

Table 16.-Estimates of homing in 23 radio-tagged Arctic grayling as determined by distance between release site (in August 1997) and location during the 28 July 1998 tracking survey.

Distance(km)	n	p	SE
0 - 1	9	0.39	0.10
1 - 2	2	0.09	0.06
2 - 3	1	0.04	0.04
3 - 4	1	0.04	0.04
4 - 5	1	0.04	0.04
5 - 6	2	0.09	0.06
6 - 7	1	0.04	0.04
7 - 8	1	0.04	0.04
8 - 9	0	---	---
9 - 10	2	0.09	0.06
10 - 27	3	0.13	0.07
Totals	23	1.00	---

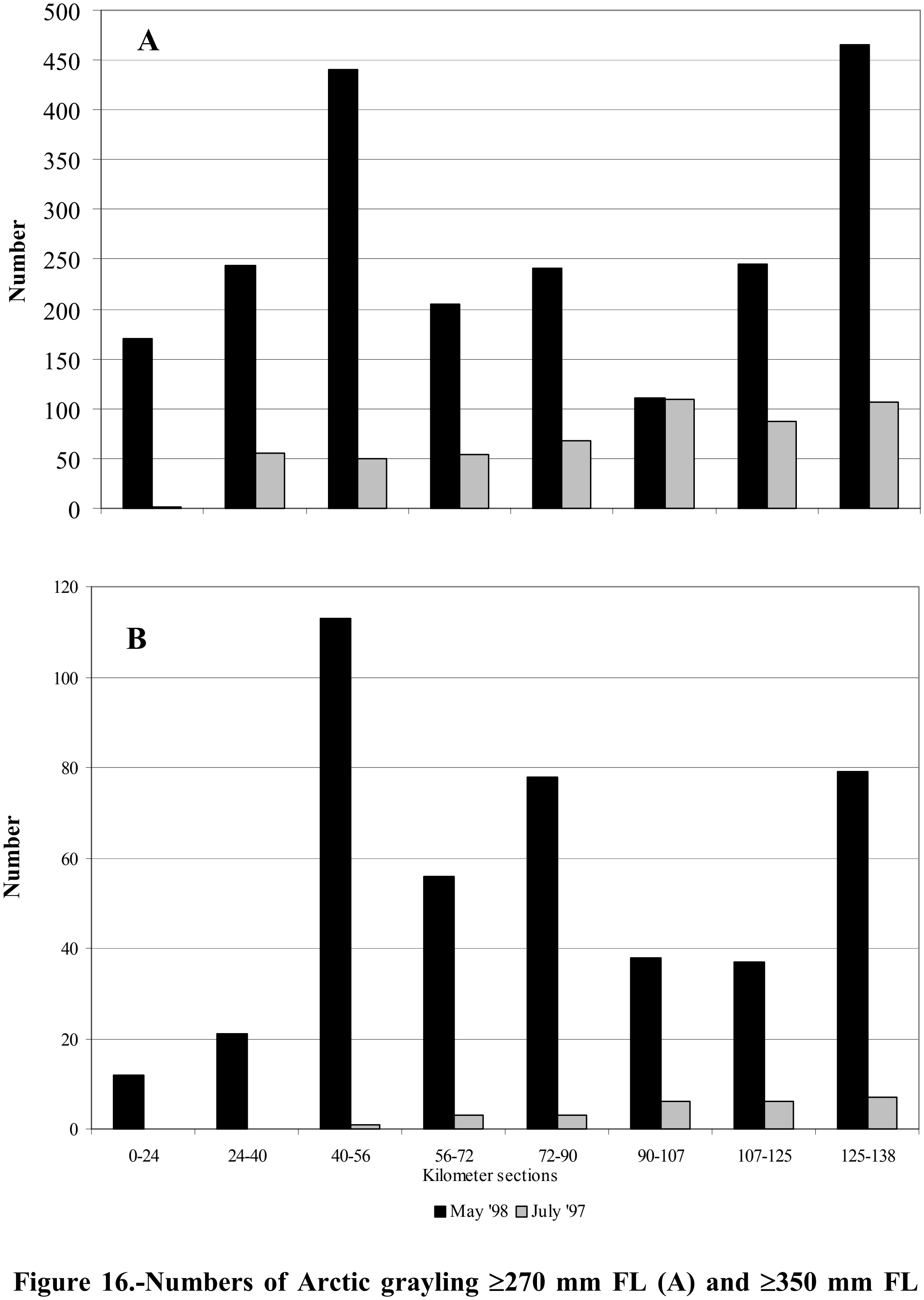


Figure 16.-Numbers of Arctic grayling ≥270 mm FL (A) and ≥350 mm FL (B) caught with an electrofishing boat during one pass through the lower Chena River in July 1997 and May 1998. Graph A shows fish of which 50% are mature (Clark 1992b) while B shows fish with the minimum length of radio-implanted fish.

MSA in September had moved the greatest distance and all were considered mortalities by the 30 October survey (Appendix C2). Conversely, two radio-implanted fish caught by anglers above the MSA one month after surgery were reported healthy with no signs of infection or fungus along the incision. However, post-surgical stress introduces another variable that can influence behavior and should be considered in planning short term telemetry studies requiring implantation.

The MSA likely encompasses the area of the drainage where the largest production occurs and contains the best rearing habitat. Thus the area is essential to studies assessing population trends and estimating production. Although estimated abundance of mature fish in the MSA in July would not represent all mature fish in the Chena River, the present stock assessment program provides more than adequate means to manage the fishery on the Chena River. Additional studies could be designed to describe the size, timing and direction of adult movement into and out of the MSA.

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LITERATURE CITED

Armstrong, R. H. 1982. Arctic grayling studies in Alaska. Alaska Cooperative Fisheries Research Unit and the Alaska Department of Fish and Game, Fairbanks, Alaska.

Armstrong, R. H., H. Hop, and J. H. Triplehorn. 1986. Indexed bibliography of the holarctic genus Thymallus (grayling) to 1985. Biological Papers of the University of Alaska No. 23, Fairbanks.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21:120-127.

Baker, T. T. 1988. Creel censuses in interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series No. 64, Juneau, Alaska.

Baker, T. T. 1989. Creel censuses in interior Alaska in 1988. Alaska Department of Fish and Game, Fishery Data Series No. 92, Juneau, Alaska.

Beauchamp, D. A. 1990. Movements, habitat use, and spawning strategies of Arctic grayling in a subalpine lake tributary. Northwest Science 64(4), 195-207.

Bernard, D. R. 1983. Variance and bias of catch allocations that use the age composition of escapements. Alaska Department of Fish and Game, Informational Leaflet No. 227, Juneau.

Bernard, D. R., and P. A. Hansen. 1992. Mark-recapture experiments to estimate abundance of fish. Alaska Department of Fish and Game, Special Publication No. 92-4, Anchorage.

LITERATURE CITED (Continued)

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

Clark, R. A. 1986. Arctic grayling stock status and population dynamics in the Tanana drainage. Pages 35-64 in Arctic-Yukon-Kuskokwim reports to the Board of Fisheries, Anchorage, Alaska. Alaska Department of Fish and Game, Sport Fish Division, 1300 College Road, Fairbanks.

Clark, R. A. 1987. Arctic grayling harvests, stock status, and regulatory concerns in the Arctic Yukon Kuskokwim Region. Pages 105-137 in Sport Fish Division report to the Alaska Board of Fisheries 1987. Alaska Department of Fish and Game, Sport Fish Division, Juneau.

Clark, R. A. 1989. Stock status of Chena River Arctic grayling. Alaska Department of Fish and Game, Fishery Data Series No. 97, Juneau.

Clark, R. A. 1990. Stock status of Chena River Arctic grayling. Alaska Department of Fish and Game, Fishery Data Series No. 90-4, Anchorage.

Clark, R. A. 1991. Stock status of Chena River Arctic grayling during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-35, Anchorage.

Clark, R. A. 1992a. Influence of stream flows and stock size on recruitment of Arctic grayling (Thymallus arcticus) in the Chena River, Alaska. Canadian Journal of Fisheries and Aquatic Science 49:1027-1034.

Clark, R. A. 1992b. Age and size at maturity of Arctic grayling in selected waters of the Tanana drainage. Alaska Department of Fish and Game, Fishery Manuscript No. 92-5, Anchorage.

Clark, R. A. 1993. Stock status and rehabilitation of Chena River Arctic grayling during 1991 and 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-5, Anchorage.

Clark, R. A. 1993. Interannual intrastream movements of Arctic grayling in the Chena, Salcha, and Goodpaster rivers. Alaska Department of Fish and Game, Fishery Manuscript No. 93-2, Anchorage.

Clark, R. A. 1994. Stock status and rehabilitation of Chena River Arctic grayling during 1993. Alaska Department of Fish and Game, Fishery Data Series No.94-5, Anchorage.

Clark, R. A. 1995. Stock status and rehabilitation of Chena River Arctic grayling during 1994. Alaska Department of Fish and Game, Fishery Data Series No.95-8, Anchorage.

Clark, R. A. 1996. Stock status and rehabilitation of Chena River Arctic grayling during 1995. Alaska Department of Fish and Game, Fishery Data Series No.96-2, Anchorage.

Clark, R. A., and W. P. Ridder. 1987a. Tanana drainage creel census and harvest surveys, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 12, Juneau.

Clark, R. A., and W.P. Ridder. 1987b. Abundance and length composition of selected grayling stocks in the Tanana drainage during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 26, Juneau.

Clark, R. A., and W.P. Ridder. 1988. Stock assessment of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 54, Juneau.

Cochran, W. G. 1977. Sampling Techniques. John Wiley & Sons, New York.

Cross, D. G. and B. Stott. 1975. The effect of electric fishing on the subsequent capture of fish. Journal of Fishery Biology 7:349-357.

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

Evenson, M. J. 1993. Seasonal movements of radio-implanted burbot in the Tanana River drainage. Alaska Department of Fish and Game, Fishery Data Series Number 93-47, Anchorage.

Fleming, D. F. 1991. Stock assessment of Arctic grayling in Piledriver Slough, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 91-71, Anchorage.

LITERATURE CITED (Continued)

Fleming, D. F. 1994a. Stock assessment of Arctic grayling and rainbow trout in Piledriver Slough during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-34, Anchorage.

Fleming, D. F., and G. J. Schisler. 1993. Stock assessment of Arctic grayling and rainbow trout in Piledriver Slough during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-8, Anchorage.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

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

Hallberg, J. E. 1977. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1976-1977, Project F-9-9, 18 (R-I).

Hallberg, J. E. 1978. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1977-1978, Project F-9-10, 19 (R-I).

Hallberg, J. E. 1979. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1978-1979, Project F-9-11, 20 (R-I).

Hallberg, J. E. 1980. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21 (R-I).

Hallberg, J. E. 1981. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1980-1981, Project F-9-13, 22 (R-I).

Hallberg, J. E. 1982. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1981-1982, Project F-9-14, 23 (R-I).

Hallberg, J. E. and A. E. Bingham. 1992. Creel surveys conducted in interior Alaska during 1991. Alaska Department of Fish and Game. Fishery Data Series No. 92-7, Anchorage.

Holmes R. A., W.P. Ridder, and R.A. Clark. 1986. Population structure and dynamics of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27 (G-8-1).

Holmes, R. A. 1983. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24 (R-I).

Holmes, R. A. 1984. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25 (R-I).

Holmes, R. A. 1985. Population structure and dynamics of Arctic grayling, with emphasis on heavily fished stocks. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26 (R-I).

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 No. 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 No. 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 No. 97-29, Anchorage.

Lorenz, W. R. 1984. Evaluation of sampling gears for fish population assessment in Alaskan streams and rivers. Master's thesis, University of Alaska, Fairbanks.

Lubinski, B. R. 1995. Winter habitat of Arctic grayling in an interior Alaska stream. M.S. Thesis, University of Alaska. 143p.

Marquardt, D. W. 1963. An algorithm for least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11:431-441.

Merritt, M. F. *Unpublished*. Ranking selected streams in interior Alaska on the bases of suitability for sustaining an introduced rainbow trout population. Alaska Dept Fish and Game, 1300 College Road, Fairbanks.

Merritt, M. F., A. E. Bingham, and N. Morton. 1990. Creel censuses conducted in interior Alaska during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-54, Anchorage.

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.

LITERATURE CITED (Continued)

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.

Northcote, T.G. 1995. Comparative biology and management of Arctic and European grayling (Salmonidae, Thymallus). Reviews in Fish Biology and Fisheries, 5, 141-194.

Ott, A. G. and P. H. Scannell 1996. Baseline fish and habitat data for Fort Knox Mine 1992 to 1995. Alaska Department of Fish and Game, Habitat and Restoration Division, Technical Report No. 96-5, Juneau.

Reynolds, J. B. 1983. Electrofishing, P. 147-163. In L. A. Nielsen and D. L. Johnson [ed.] Fisheries techniques. American Fisheries Society, Bethesda, MD.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191.

Ridder, W. P. 1989. Age, length, sex,, and abundance of Arctic grayling in the Goodpaster River, 1956 through 1988, Fishery Data Series No. 94, Juneau.

Ridder, W. P. 1997. Stock status of Arctic grayling in the Chena River and Badger Slough during 1996. Alaska Department of Fish and Game, Fishery Data Series No.97-30, Anchorage.

Ridder, W. P. *In prep*. Stock status and radio telemetry of Arctic grayling in the Chena River. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Ridder, W. and D. Fleming. 1997. Stock status of Arctic grayling in the Chena River and Badger Slough during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-30, Anchorage.

Roguski, E. A. and P. Winslow. 1969. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Federal Aid in Fish Restoration, Annual Report of Progress, 1968-1969, Project F-9-1, 10 (16-B):333-351.

Roguski, E. A. and S. L. Tack. 1970. Investigations of the Tanana River and Tangle Lakes grayling fisheries: migratory and population study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1969-1970, Project F-9-2, 11 (16-B):303-319.

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

Tack, S. L. 1971. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1970-1971, Project F-9-3, 12 (R-I).

Tack, S. L. 1972. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972, Project F-9-4, 13 (R-I).

Tack, S. L. 1973. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14 (R-I).

Tack, S. L. 1974. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974, Project F-9-6, 15 (R-I).

Tack, S. L. 1975. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16 (R-I).

LITERATURE CITED (Continued)

Tack, S. L. 1976. Distribution, abundance, and natural history of Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1975-1976, Project F-9-8, 17 (R-I).

Tack, S. L. 1980. Migrations and distributions of Arctic grayling, Thymallus arcticus (Pallas), in interior and arctic Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Summary Report, 1971-1980, Project F-9-12, 21 (R-I).

Van Hulle, F. D. 1968. Investigations of the fish populations in the Chena River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1967-1968, Project F-5-R-9, 9:287-304

Warner, G. 1959. Catch distribution, age and size composition sport fish in Fairbanks area. U.S. Fish and Wildlife Service, Federal Aid in Fish Restoration, Quarterly Progress Report. Project F-1-R-8, Work Plan A, Job 3c, 8(3).

West, R. L., M. W. Smith and three co-authors. 1992. Autumn migration and overwintering of Arctic grayling in coastal streams of the Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 121:709-715.

Wojcik, F. J. 1955. Life history and management of the grayling in interior Alaska. M.S. Thesis, University of Alaska - Fairbanks.

APPENDIX A
Historic Data Summary

Appendix A1.-Summary of population abundance estimates of wild Arctic grayling (> 150 mm FL) in the Chena River, 1968-1996.

Year	Dates	Area[a]	Estimator[b]	Estimate	Confidence[c]
1968	Summer?	2	SN	411/km	393-1,209
	Summer?	6	SN	283/km	228-381
1969	June?	2	SN	596/km	474-850
	June?	6	SN	571/km	439-816
1970	7/02-7/10	2	SN	919/km	690-1,519
	5/26-5/30	6	SN	373/km	346-408
	6/08-7/08	9B	SN	1,005/km	803-1,411
	6/07-7/07	10	SN	1,171/km	876-1,957
1971	8/30-9/03	2A	SN	300/km	192-1,157
	6/02-6/07	2B	SN	1,302/km	958-2,305
	8/30-9/03	2B	SN	2,338/km	1,753-3,897
	6/21-6/24	6	SN	189/km	161-233
1972	6/22-6/26	2A	SN	309/km	236-489
	6/22-6/26	2B	SN	608/km	493-828
	6/19-6/20	6	SN	159/km	124-235
	6/27-6/29	DS	SN	812/km	604-1,393
1973	7/10-7/13	2A	SN	293/km	218-502
	7/03-7/14	2B	SN	424/km	354-545
	7/16-7/17	6	SN	243/km	203-312
	7/18-7/19	DS	SN	500/km	379-806
1974	6/26-6/28	2A	SE	65/km	36-372
	6/25-6/28	2B	SE	488/km	207-1,378
	8/13-8/15	6	SE	100/km	71-164
	7/09-7/11	DS	SE	263/km	221-326
1975	7/10-7/14	6	SE	191/km	114-589
1976	7/19-7/21	2A	SE	258/km	223-307
	7/22-7/24	2B	SE	409/km	323-556
	7/28-7/30	6	SE	163/km	153-175
	8/04-8/06	DS	SE	306/km	285-329
1977	7/05-7/08	2A	SE	318/km	298-343
	7/11-7/14	2B	SE	318/km	280-370
		6	SE	173/km	170-177
		DS	SE	315/km	283-359
1978	7/14-7/17	2A	SE	69/km	44-156
	7/25-7/28	2B	SE	162/km	148-179
	7/10-7/13	6	SE	226/km	210-243
	8/08-8/11	DS	SE	345/km	333-359

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Year	Dates	Area[a]	Estimator[b]	Estimate	Confidence[c]
1979	7/01-7/03	2A	SE	57/km	45-76
	6/26-6/30	2B	SE	201/km	188-216
	8/20-8/23	8A	SE	177/km	161-197
	7/17-7/20	DS	SE	193/km	144-288
1980	7/01-7/04	2B	SE	308/km	229-471
	7/14-7/17	8A	SE	190/km	154-248
	7/29-8/01	DS	SE	236/km	200-287
	8/12-8/15	10B	SE	842/km	640-1,234
1981	8/07-8/10	2B	SN	262/km	223-392
	8/03-8/06	8A	SN	224/km	164-309
	8/11-8/14	DS	SN	302/km	174-440
	7/21-7/24	10B	SN	869/km	466-1,778
1982	7/16-7/20	2B	SN	116/km	79-177
	7/13-7/15	8A	SN	87/km	60-132
	7/23-7/27	DS	SN	232/km	113-579
	7/28-7/30	10B	SN	875/km	529-1,563
1983	7/13-7/15	2B	SN	216/km	168-265
	7/5-7/7	8A	SN	119/km	81-545
	7/8,7/11-7/12	DS	SN	209/km	149-303
	7/26-7/28	10B	SN	911/km	647-1,338
	7/19-7/21	12	SN	208/km	138-332
1984	7/16-7/18	2B	SN	211/km	167-268
	7/3,7/5-7/6	8A	SN	139/km	95-215
	7/9-7/11	DS	SN	179/km	124-273
	7/19-7/20	10B	P	493/km	275-1,003
	7/31,8/2-8/3	12	SN	1,318/km	449-6,592
1985	7/10-7/17	2B	SN	189/km	92-287
	6/26-7/2	8A	SN	271/km	189-360
	7/3-7/8	DS	SN	333/km	234-432
	7/22-7/31	10B	SN	1,156/km	304-3,035
	6/12-6/24	12	SN	1,092/km	552-1,643
1986	7/7-8/6	WC	EXP	61,581	SE=26,987
1987	6/27-7/30	WC	EXP+P	31,502	SE=3,500
1988	6/26-8/04	WC	EXP+P	22,204	SE=2,092
1989	7/10-8/3	WC	EXP+P	19,028	SE=1,578
1990	7/2-8/3	WC	EXP+P	31,815	SE=4,880
1991	7/8-8/1	WC	P	26,756	SE=3,286

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Year	Dates	Area[a]	Estimator[b]	Estimate	Confidence[c]
1992	7/6-7/30	WC	P	29,349	SE=2,341
1993	7/6-7/29	WC	P	39,618	SE=4,836
1994	7/5-7/29	WC	P	44,375	SE=2,964
1995	7/5-7/27	WC	P	45,114	SE=4,356
1996	7/8-7/18	WC	P	41,463	SE=4,032

[a] areas are taken from Hallberg (1980); WC= Whole Chena River (lower 152 km).

[b] Estimators are: SN=Schnabel; SE=Schumacher-Eshmeyer, P=Petersen (Ricker 1975); EXP=Expanded estimates (Clark and Ridder 1987b); EXP+P=expanded estimates and a Petersen estimate (Clark and Ridder 1988).

[c] Confidence is either the 95% confidence interval or the standard error (SE) of the estimate.

[d] Estimates do not include Arctic grayling stocked in 1992 through 1994.

Appendix A2.-Source citations for Federal Aid and Fishery Data Reports used for data summaries, 1955-1958 and 1967-1996.

Year	Type of Data[a]	Source Document
1955	CC	Warner (1959)
1956	CC	Warner (1959)
1957	CC	Warner (1959)
1958	CC	Warner (1959)
1967	AL, CC, POP	Van Hulle (1968)
1968	AL, CC, POP	Roguski and Winslow (1969)
1969	CC, POP	Roguski and Tack (1970)
1970	POP	Tack (1971)
1971	CC, POP	Tack (1972)
1972	AL, POP	Tack (1973)
1973	AL, CC, POP	Tack (1974)
1974	AL, CC, POP	Tack (1975)
1975	AL, CC, POP	Tack (1976)
1976	AL, CC, POP	Hallberg (1977)
1977	AL, CC, POP	Hallberg (1978)
1978	AL, CC, POP	Hallberg (1979)
1979	AL, CC, POP	Hallberg (1980)
1980	AL, CC, POP	Hallberg (1981)
1981	AL, CC, POP	Hallberg (1982)
1982	AL, CC, POP	Holmes (1983)
1983	AL, CC, POP	Holmes (1984)
1984	AL, CC, POP	Holmes (1985)
1985	AL, CC, POP	Holmes et al. (1986)
1986	CC	Clark and Rider (1987a)
	AL, POP	Clark and Rider (1998b)
1987	CC	Baker (1988)
	AL, POP	Clark and Rider (1988)
1988	CC	Baker (1989)
	AL, POP	Clark (1989)
1989	CC	Merritt et al. (1990)
	AL, POP	Clark (1990)
1990	AL, POP	Clark (1991)
1991	AL, POP	Clark (1993)
	CC	Hallberg and Bingham (1992)
1992	AL, POP	Clark (1993)
1993	AL, POP	Clark (1994)
1994	AL, POP	Clark (1995)
1995	AL, POP	Clark (1996)
1996	AL, POP	Rider and Fleming (1997)

[a] CC = Creel census estimates; AL = age and size composition estimates; and, POP = population abundance estimates.

Appendix A3.-Summary of catch statistics and abundance for all Arctic grayling ≥ 150 mm FL during mark-recapture experiments in the Lower and Upper Chena River, 1987-1997.

Lower Chena River:

Year	Mark (M)	Catch (C)	Recap (R)	M+C-R	R/M[a]	R/C[b]	N[c]	SE [N]
1991	1,156	848	180	1,824	0.16	0.21	6,526	701
1992	1,756	1,371	287	2,840	0.16	0.21	11,316	1,294
1993	2,620	1,939	234	4,325	0.09	0.12	24,790	2,011
1994	2,385	3,130	250	5,265	0.10	0.08	33,362	3,157
1995	1,458	1,873	168	3,163	0.12	0.09	17,723	1,698
1996	978	2,247	143	3,082	0.15	0.06	15,268	1,226
1997	673	581	34	1,219	0.05	0.06	12,434	2,444

Upper Chena River:

Year	Mark (M)	Catch (C)	Recap (R)	M+C-R	R/M	R/C	N	SE [N]
1987	922	988	43	1,867	0.05	0.04	24,446	3,364
1988	1,291	1,307	116	2,482	0.09	0.09	14,444	1,210
1989	1,255	952	84	2,123	0.07	0.09	14,863	
1990	1,539	1,513	139	2,913	0.09	0.09	19,061	1,108
1991	1,097	901	59	1,939	0.05	0.07	20,230	3,210
1992	1,363	1,375	115	2,623	0.08	0.08	18,033	1,950
1993	2,092	2,205	105	4,192	0.05	0.05	47,889	5,433
1994	2,882	2,904	163	5,623	0.06	0.06	56,640	5,112
1995	1,745	1,397	99	3,043	0.06	0.07	31,731	4,502
1996	1,099	1,453	63	2,489	0.06	0.04	27,582	3,978
1997	705	863	22	1,546	0.03	0.03	nd	nd

[a] R/M= recapture rate.

[b] R/C= capture probability.

[c] N= estimated abundance of Arctic grayling > 150 mm FL both wild and stocked. Estimates will not all compute with catch statistics due to length stratification in most years.

Appendix A4.-Catch statistics from river kilometers 8 to 24 (from Princess Hotel upstream to Trainor Gate Road) within the Lower Chena River study section, 1991-1997.

Year	Statistic	Mark (M)	Catch (C)	Recap (R)	M+C-R
1991	N[a]	1,162	867	176	1,853
	n[b]	157	154	11	300
	P[c]	0.14	0.18	0.06	0.16
	SE[p]	0.01	0.01	0.02	0.01
1992	N	1,770	1,374	279	2,865
	n	268	185	20	433
	P	0.15	0.13	0.07	0.15
	SE[p]	0.01	0.01	0.02	0.01
1993	N	2,634	1,940	232	4,237
	n	503	327	34	745
	P	0.19	0.17	0.15	0.18
	SE[p]	0.01	0.01	0.02	0.01
1994	N	2,387	3,132	250	5,269
	n	650	531	50	1,131
	P	0.27	0.17	0.20	0.21
	SE[p]	0.01	0.01	0.03	0.01
1995	N	1,458	1,873	168	3,163
	n	293	521	35	779
	P	0.20	0.28	0.21	0.25
	SE[p]	0.01	0.01	0.03	0.01
1996	N	2,241	978	142	3,077
	n	431	212	28	618
	P	0.19	0.22	0.20	0.20
	SE[p]	0.01	0.01	0.03	0.01
1997	N	673	581	34	1,220
	n	57	52	1	108
	P	0.08	0.09	0.03	0.09
	SE[p]	0.01	0.01	0.03	0.01

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Year	Statistic	Mark (M)	Catch (C)	Recap (R)	M+C-R
1991-1996	N'[d]	1,942	1,694	208	3,411
	n'[e]	384	322	30	668
	P	0.20	0.19	0.14	0.20
	SE[p]	0.01	0.01	0.02	0.01

[a] N = catch for Lower Chena River section (river kilometer 8 to river kilometer 72).

[b] n = catch for river kilometer 8 to river kilometer 24.

[c] p = proportion of catch from river kilometer 8 to river kilometer 24.

[d] N' = average of N.

[e] n' = average of n.

Appendix A5.-Summary of Arctic grayling creel census on the Chena River, 1955-1958, 1967-1970, 1972, 1974-1989, and 1991.

Year	Dates	Area	Angler Hours	Harvest	CPUE	Mean Length
1955	ND	Lower Chena	---	---	0.89	226
1956	ND	Lower Chena	---	---	0.95	251
1957	ND	Lower Chena	---	---	0.62	246
1958	ND	Lower Chena	---	---	0.88	226
1967	4/10 to 8/11	Entire Chena	12,885	---	0.32	245
1968	5/1 to 9/2	Entire Chena	10,269	5,643	0.55	251
1969	7/1 to 9/30	Entire Chena	7,998	7,686	0.96	263
1970	5/1 to 5/30 & 7/1 to 8/31	Entire Chena	12,518	6,770	0.54	---
1972	5/25 to 8/27	Lower Chena	13,116	10,099	0.77	---
1974	7/1 to 8/31	Upper Chena	11,680	18,049	1.72	---
1975	6/1 to 8/31	Upper Chena	22,657	14,067	0.62	252
1976	6/1 to 8/31	Upper Chena	10,762	4,161	0.39	230
1977	6/1 to 8/31	Upper Chena	13,563	9,406	0.71	208
1978	5/29 to 8/31	Upper Chena	10,508	6,898	0.65	222
1979	6/1 to 8/31	Upper Chena	12,564	8,544	0.69	240
1980	5/8 to 9/30	Upper Chena	20,827	16,390	0.78	256
1981	5/1 to 8/31	Upper Chena	15,896	13,549	0.80	---
1982	5/1 to 9/15	Upper Chena	20,379	12,603	0.62	248
1983	5/1 to 9/15	Upper Chena	19,018	10,821	0.58	260
1984	5/6 to 9/15	Upper Chena	17,090	9,623	0.59	278
1985	5/8 to 9/5	Upper Chena	10,613	2,367	0.22	273
1986	5/10 to 9/15	Upper Chena	10,716	3,326	0.31	271
1987	5/18 to 9/15	Upper Chena	9,090	1,260	0.14	290
1988	5/14 to 9/13	Upper Chena	11,763	1,583	0.13	287
1989	5/19 to 9/13	Upper Chena	11,349	3,325	0.21	295
1991	5/18 to 7/31	Upper Chena[a]	3,201	---	---	280

[a] Only road km 43 through 73 of the Chena Hot Springs Road.

Appendix A6.-Summary of age composition estimates of Arctic grayling in the Chena River, 1967-1969 and 1973-1996.

	Age 0		Age 1		Age 2		Age 3		Age 4		Age 5		Age 6	
Year	$\hat{p}$ [a]	SE [b]	$\hat{p}$	SE	$\hat{p}$	SE	$\hat{p}$	SE	$\hat{p}$	SE	$\hat{p}$	SE	$\hat{p}$	SE
1967	0.10	0.02	0.013	0.02	0.13	0.02	0.06	0.01	0.17	0.02	0.25	0.02	0.11	0.02
1968	0.09	0.03	0.21	0.04	0.24	0.04	0.25	0.04	0.13	0.03	0.03	0.01	0.05	0.02
1969	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.06	0.38	0.07	0.12	0.05	0.16	0.05
1973	0.00	0.00	0.06	0.02	0.13	0.02	0.61	0.03	0.18	0.03	0.03	0.01	0.00	0.00
1974	0.00	0.00	0.04	0.01	0.11	0.02	0.12	0.02	0.44	0.03	0.25	0.02	0.04	0.01
1975	0.00	0.00	0.00	0.00	0.13	0.04	0.25	0.05	0.13	0.04	0.26	0.05	0.19	0.04
1976	0.00	0.00	0.10	0.02	0.24	0.03	0.29	0.03	0.15	0.02	0.09	0.02	0.11	0.02
1977	0.00	0.00	0.06	0.02	0.34	0.03	0.45	0.03	0.08	0.02	0.06	0.02	0.02	0.01
1978	0.00	0.00	0.15	0.02	0.38	0.03	0.22	0.03	0.21	0.02	0.03	0.01	0.01	0.01
1979	0.00	0.00	0.11	0.02	0.20	0.03	0.45	0.03	0.17	0.03	0.05	0.01	0.00	0.00
1980	0.00	0.00	0.02	0.01	0.12	0.02	0.39	0.03	0.28	0.03	0.13	0.02	0.05	0.01
1981	0.00	0.00	0.16	0.02	0.13	0.02	0.40	0.02	0.12	0.02	0.12	0.02	0.06	0.01
1982	0.00	0.00	0.06	0.01	0.30	0.03	0.11	0.02	0.35	0.03	0.09	0.02	0.04	0.01
1983	0.01	0.01	0.07	0.01	0.11	0.01	0.45	0.02	0.08	0.01	0.17	0.02	0.06	0.01
1984	0.00	0.00	0.19	0.02	0.07	0.01	0.12	0.02	0.41	0.02	0.08	0.01	0.09	0.01
1985	0.00	0.00	0.02	0.00	0.16	0.01	0.11	0.01	0.14	0.01	0.32	0.01	0.10	0.01
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.01	0.07	0.01	0.09	0.01	0.13	0.01
1987	0.00	0.00	0.00	0.00	0.05	0.01	0.08	0.01	0.60	0.03	0.07	0.01	0.05	0.01
1988	0.00	0.00	0.00	0.00	0.09	0.02	0.15	0.02	0.12	0.02	0.42	0.04	0.07	0.01
1989	0.00	0.00	0.00	0.00	0.15	0.02	0.23	0.03	0.14	0.02	0.14	0.02	0.22	0.03
1990	0.00	0.00	0.00	0.00	0.08	0.04	0.53	0.08	0.10	0.03	0.08	0.02	0.07	0.02
1991	0.00	0.00	0.00	0.00	0.08	0.01	0.11	0.01	0.52	0.02	0.11	0.01	0.07	0.01
1992	0.00	0.00	0.00	0.00	0.14	0.02	0.20	0.01	0.15	0.01	0.38	0.02	0.05	0.00
1993	0.00	0.00	0.00	0.00	0.14	0.01	0.48	0.03	0.12	0.01	0.09	0.01	0.11	0.02
1994	0.00	0.00	0.00	0.00	0.11	0.01	0.29	0.03	0.34	0.03	0.07	0.01	0.07	0.01
1995	0.00	0.00	0.00	0.00	0.31	0.02	0.14	0.01	0.24	0.02	0.19	0.01	0.06	0.01
1996	0.00	0.00	0.00	0.00	0.04	<0.01	0.38	0.02	0.11	0.01	0.17	0.01	0.14	0.01

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	Age 7		Age 8		Age 9		Age 10		Age 11+	
Year	p̂	SE	p̂	SE	p̂	SE	p̂	SE	p̂	SE
1967	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1968	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1969	0.06	0.03	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1973	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1974	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1975	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1976	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.10	0.01	0.04	0.00	0.02	0.00	0.00	0.00	0.00	0.00
1986	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.10	0.02	0.02	0.01	0.02	0.00	0.00	0.00	0.00	0.00
1988	0.06	0.01	0.07	0.01	0.02	0.00	0.00	0.00	0.00	0.00
1989	0.06	0.01	0.04	0.01	0.03	0.01	0.00	0.00	0.00	0.00
1990	0.09	0.02	0.02	0.01	0.01	0.00	<0.01	0.00	<0.01	0.00
1991	0.06	0.01	0.04	0.01	<0.01	0.00	<0.01	0.00	<0.01	0.00
1992	0.04	0.00	0.03	0.00	0.01	0.00	<0.01	0.00	<0.01	0.00
1993	0.02	0.00	0.02	0.00	0.01	0.00	0.01	0.00	<0.01	0.00
1994	0.07	0.01	0.02	0.00	0.01	0.00	<0.01	0.00	<0.01	0.00
1995	0.04	0.01	0.02	<0301	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1996	0.07	0.01	0.05	0.01	0.03	0.01	0.02	<0.01	0.01	<0.01

[a] $\hat{p}$ = estimated proportion at age.

[b] SE = the standard error of $\hat{p}$.

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Appendix A7.-Summary of mean length at age estimates of Arctic grayling from the Chena River, 1967-1969 and 1973-1996.

	Age 0		Age 1		Age 2		Age 3		Age 4		Age 5		Age 6	
Year	n[a]	FL[b]	n	FL	n	FL	n	FL	n	FL	n	FL	n	FL
1967	30	25	41	135	41	186	17	243	51	272	77	293	32	321
1968	10	73	24	103	28	150	29	214	15	255	3	289	6	304
1969	0	---	0	---	0	---	11	191	19	236	6	273	8	304
1973	0	---	11	111	25	167	121	194	36	215	6	279	0	---
1974	0	---	12	130	32	169	37	199	133	217	76	236	12	259
1975	0	---	0	---	12	171	22	200	12	229	23	238	17	258
1976	0	---	26	144	61	175	74	194	39	221	24	249	28	270
1977	0	---	14	112	77	176	102	208	19	245	13	263	4	299
1978	0	---	39	128	102	167	59	206	56	230	9	256	2	290
1979	0	---	25	107	44	165	99	197	38	236	11	266	1	310
1980	0	---	4	114	31	154	97	198	71	231	33	259	12	292
1981	0	---	61	112	48	162	152	187	46	215	47	240	22	268
1982	0	---	19	105	88	137	34	190	105	215	26	251	11	279
1983	0	62	33	114	53	151	215	177	38	216	83	239	29	273
1984	0	---	82	97	32	153	54	182	179	213	36	226	40	257
1985	0	---	42	108	300	141	203	188	267	215	609	233	182	285
1986	0	---	40	109	104	164	755	184	79	220	110	251	153	270
1987	0	---	0	---	54	160	92	204	691	228	115	274	76	292
1988	0	---	7	108	135	172	238	216	181	239	707	260	118	288
1989	0	---	17	123	285	156	295	215	205	254	245	272	423	285
1990	0	---	13	129	134	174	840	207	232	251	223	280	221	298
1991	0	---	0	---	143	177	211	215	863	241	227	273	177	298
1992	0	---	0	---	224	165	384	209	450	239	1046	262	214	288
1993	0	---	0	---	172	167	605	207	252	248	243	274	282	286
1994	0	---	0	---	274	177	512	199	721	236	228	258	202	277
1995	0	---	0	---	697	176	384	213	493	242	513	270	186	294
1996	0	---	0	---	158	165	1151	199	355	232	437	259	371	278
Ave		40		114		159		198		230		255		285

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	Age 7		Age 8		Age 9		Age 10		Age 11+	
Year	n	FL	n	FL	n	FL	n	FL	n	FL
1967	15	335	0	---	0	---	0	---	0	---
1968	2	372	0	---	0	---	0	---	0	---
1969	3	317	3	356	0	---	0	---	0	---
1973	1	310	0	---	0	---	0	---	0	---
1974	1	315	0	---	0	---	0	---	0	---
1975	2	275	1	320	0	---	0	---	0	---
1976	4	308	0	---	0	---	0	---	0	---
1977	0	---	0	---	0	---	0	---	0	---
1978	1	325	0	---	0	---	0	---	0	---
1979	0	---	0	---	0	---	0	---	0	---
1980	3	327	0	---	0	---	0	---	0	---
1981	5	287	3	310	0	---	0	---	0	---
1982	7	305	6	337	0	---	0	---	0	---
1983	13	307	7	338	0	---	0	---	0	---
1984	7	275	6	321	0	---	0	---	0	---
1985	188	285	80	308	30	377	2	377	0	---
1986	42	301	22	318	5	330	1	346	0	---
1987	184	309	30	324	31	338	2	353	0	---
1988	95	313	110	325	35	347	7	337	2	374
1989	112	314	73	329	54	347	5	372		
1990	284	308	63	332	43	340	17	362	2	359
1991	199	303	135	316	23	335	19	347	3	338
1992	157	307	134	312	57	321	20	338	6	347
1993	58	313	55	322	32	341	13	353	4	348
1994	178	296	52	309	29	331	15	332	4	367
1995	126	311	84	331	15	341	7	366	2	367
1996	221	291	154	314	87	323	48	340	24	357
Ave		305		323		348		358		366

[a] n = sample size.

[b] FL = the estimated mean fork length in millimeters.

Appendix A8.-Summary of Relative Stock Density (RSD) indices of Arctic grayling (>150 mm FL) captured by electrofishing from the Chena River, 1972-1996.

	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1972 (2A,2B,6,DS)-6/19-622					
Sample size	1,392	42	3	0	0
RSD	0.97	0.03	<0.01	0.00	0.00
Standard Error	0.01	<0.01	<0.01	0.00	0.00
1973 (2A,2B,6,DS)-7/3-7/19					
Sample size	176	7	0	0	0
RSD	0.96	0.04	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1974 (2A,2B,6,DS)-6/25-8/15					
Sample size	889	58	0	0	0
RSD	0.94	0.06	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1975 (6)-7/10-7/14					
Sample size	76	13	0	0	0
RSD	0.85	0.15	0.00	0.00	0.00
Standard Error	0.04	0.04	0.00	0.00	0.00
1976 (2A,2B,6,DS)-7/19-8/6					
Sample size	613	59	1	0	0
RSD	0.91	0.09	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1977 (2A,2B,6,DS)-7/5-7/30					
Sample size	916	30	0	0	0
RSD	0.967	0.03	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00
1978 (2A,2B,6,DS)-7/10-8/11					
Sample size	841	20	0	0	0
RSD	0.98	0.02	0.00	0.00	0.00
Standard Error	0.01	0.01	0.00	0.00	0.00

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	RSD Category[a]				
	Stock	Quality	Preferred	Memorab le	Trophy
1979 (2A,2B,8A,DS)-6/26-8/23					
Sample size	802	13	0	0	0
RSD	0.98	0.02	0.00	0.00	0.00
Standard Error	<0.01	<0.01	0.00	0.00	0.00
1980 (2B,8A,DS,10B)-7/1-8/15					
Sample size	1,260	53	2	0	0
RSD	0.96	0.04	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.00	0.00	0.00
1981 (2B,8A,DS,10B)-7/21-8/14					
Sample size	1,247	42	1	0	0
RSD	0.97	0.03	<0.01	0.00	0.00
Standard Error	<0.01	<0.01	<0.00	0.00	0.00
1982 (2B,8A,DS,10B)-7/13-7/30					
Sample size	919	76	5	0	0
RSD	0.92	0.08	0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1983 (2B,8A,DS,10B,12)-7/5-7/28					
Sample size	1,560	152	10	0	0
RSD	0.91	0.09	0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1984 (2B,8A,DS,10B,12)-7/3-8/3					
Sample size	1,349	74	4	0	0
RSD	0.95	0.05	<0.01	0.00	0.00
Standard Error	0.01	0.01	<0.01	0.00	0.00
1985 (2B,8A,DS,10B,12)-6/12-7/31					
Sample size [c]	ND	ND	ND	ND	ND
RSD	---	---	---	---	---
Standard Error	---	---	---	---	---

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	RSD Category[a]				
	Stock	Quality	Preferred	Memorab le	Trophy
1987 (lower 152 km)-6/27-7/30					
Sample size	1,678	693	154	0	0
RSD	0.67	0.27	0.06	0.00	0.00
Adjusted RSD [d]	0.78	0.19	0.03	0.00	0.00
Standard Error[e]	0.04	0.04	0.01	0.00	0.00
1988 (lower 1252 km)-6/26-8/4					
Sample size [f]	1,855	1,242	217	0	0
RSD	0.63	0.32	0.05	0.00	0.00
Standard Error	0.04	0.03	0.01	0.00	0.00
1989 (lower 152 km)-7/10-8/3					
Sample size [f]	1,363	1,340	184	0	0
RSD	0.47	0.46	0.06	0.00	0.00
Adjusted RSD [d]	0.57	0.38	0.05	0.00	0.00
Standard Error [e]	0.04	0.04	0.01	0.00	0.00
1990 (lower 152 km)-7/2-8/3					
Sample size [f]	2,239	1,389	255	0	0
RSD	0.58	0.36	0.06	0.00	0.00
Adjusted RSD [d]	0.75	0.21	0.04	0.00	0.00
Standard Error [e]	0.17	0.03	0.01	0.00	0.00
1991 (lower 152 km)-7/8-8/1					
Sample size [f]	2,587	1,185	178	0	0
RSD	0.65	0.30	0.05	0.00	0.00
Adjusted RSD [d]	0.73	0.24	0.03	0.00	0.00
Standard Error [e]	0.01	0.01	<0.01	0.00	0.00
1992 (lower 152 km)-7/6-7/30					
Sample size [f]	2,068	949	102	0	0
RSD	0.66	0.31	0.03	0.00	0.00
Adjusted RSD [d]	0.78	0.20	0.02	0.00	0.00
Standard Error [e]	0.04	0.02	<0.01	0.00	0.00

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	RSD Category[a]				
	Stock	Quality	Preferred	Memorable	Trophy
1993 (lower 152 km)-7/6-7/29					
Sample size [f]	1,370	613	84	0	0
RSD	0.66	0.30	0.04	0.00	0.00
Adjusted RSD [d]	0.79	0.19	0.02	0.00	0.00
Standard Error [e]	0.03	0.03	<0.01	0.00	0.00
1994 (lower 1252 km)-7/5-7/29					
Sample size [f]	2,425	717	109	0	0
RSD	0.75	0.22	0.03	0.00	0.00
Adjusted RSD [d]	0.80	0.17	0.03	0.00	0.00
Standard Error [e]	0.02	0.01	<0.01	0.00	0.00
1995 (lower 152 km)-7/5-7/27					
Sample size [f]	2,080	785	96	0	0
RSD	0.70	0.27	0.03	0.00	0.00
Adjusted RSD [d]	0.80	0.18	0.02	0.00	0.00
Standard Error [e]	0.02	0.02	<0.01	0.00	0.00
1996 (lower 152 km)-7/8-7/18					
Sample size [f]	2,356	1,058	153	0	0
RSD	0.66	0.30	0.04	0.00	0.00
Adjusted RSD [d]	0.66	0.30	0.04	0.00	0.00
Standard Error [e]	0.02	0.02	0.01	0.00	0.00

[a] Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.

[b] Year (sections sampled (taken from Hallberg 1980) – sampling dates.

[c] Lengths were taken in 1985, but not reported in Holmes et al. (1986).

[d] RSD was adjusted to correct for bias due to the electrofishing boat (Clark and Rider 1988).

[e] Standard error is for adjusted RSD only.

[f] Sample sizes do not correspond to RSD proportions because RSD proportions are weighted by abundance estimates in a stratified design (Clark 1989) and RSD is adjusted to correct for bias due to the electrofishing boat (Clark and Rider 1988).

Appendix A9.-Parameter estimates and standard errors of the von Bertalanffy growth model[a] for Arctic grayling from the Chena River, 1986-1993.

Parameter	Estimate	Standard Error
$L\infty^{b}$	400	9
K^{c}	0.18	0.01
$t_{\cdot}^{d}$	-1.11	0.14
$Corr(L\infty,K)^{e}$	-0.97	---
$Corr\ (L\infty,t)$	-0.86	---
$Corr\ (K,t)$	0.95	---
Sample Size	11,768	

[a] The form of the von Bertalanffy growth model (Ricker 1975) is as follows: $lt = L\infty\ (1 - \exp(-K\ (t-t_o)))$. The parameters of this model were estimated with data collected during 1986 through 1993. This model was fitted to the data by nonlinear regression utilizing the Marquardt compromise (Marquardt 1963). The range of ages used to model growth was age-2 through age-12.

[b] $L\infty$ is the length a fish would achieve if it continued to live and grow indefinitely (Ricker 1975).

[c] *K* is a constant that determines the rate of increase of growth increments (Ricker 1975).

[d] t_o represents the hypothetical at which a fish would have zero length (Ricker 1975).

[e] *Corr (x,y)* is the correlation of parameter estimates x and y.

Appendix A10.-Chena River study sections used from 1968 to 1985.[a]

Section Number	Section Name	River Kilometers	Length in Kilometers
1	River mouth to University Ave.	0-9.6	9.6
2A	University Ave. to Peger Road	9.6-12.8	3.2
2B	Peger Road to Wendell Street	12.8-17.6	4.8
3	Wendell St. to Wainwright Bridge	17.6-23.2	5.6
4	Wainwright Bridge to Badger Slough	23.2-34.4	11.2
5	Badger Slough		26.4
6	Badger Slough to Little Chena R.	34.4-39.2	4.8
7	Little Chena River		98.4
8	Little Chena to Nordale Slough	39.2-49.6	10.4
DS	Nordale Slough to Bluffs	49.6-88.8	39.2
9B	Bluffs to Bailey Bridge	88.8-100.8	12.0
10	Bailey Bridge to Hodgins Slough	100.8-126.4	25.6
11	Hodgins Slough to 90 Mi Slough	126.4-144.0	17.6
12	90 Mi Slough to First Bridge	144.0-147.2	3.2
13	First Bridge to Second Bridge	147.2-151.2	4.0
14	Second Bridge to North Fork	151.2-163.2	12.0
15	North Fork of Chena River		56.0
16	East Fork of Chena River		99.2
17	West Fork of Chena River		56.0

[a] Taken from Hallberg 1980.

APPENDIX B
Data File Listing

Appendix B1.-Data files[a] used to estimate parameters of the Arctic grayling population in the Chena River in 1997.

Data File	Description
U002ALAA.DTA	Population and marking data (first event) for Arctic grayling captured in the Lower Chena section of the Chena River (river kilometer 0 to 72) 30 June through 3 July 1997.
U002BLAA.DTA	Population and marking data (second event) for Arctic grayling captured I the Lower Chena section of the Chena River (river kilometer 0 to 72) 14 through 17 July 1997.
U001ELAA.DTA	Population and marking data (first event) for Arctic grayling captured in the Upper Chena section of the Chena River (river kilometer 72 to 152) 30 June through 3 July 1997.
U001FLAA.DTA	Population and recapture data (second event) for Arctic grayling captured in the Upper Chena section of the Chena River (river kilometer 72 to 152) 14 through 17 July 1997.

[a] Data files have been archived at, and are available from the Alaska Dept Fish and Game, Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX C

Appendix C1.-Length, weight, sex, and location of Arctic grayling implanted with radio tags in five areas of the Chena River, August 1997.

Date	Location	River Kilometer	Fish ID	Frequency	Length	Weight (g)	Sex
8/12/97	East Fork	2	EF1	149.330	380	540	M
8/8/97	East Fork	7	EF2	149.549	354	456	M
8/8/97	East Fork	14	EF3	149.270	356	435	M
8/8/97	East Fork	19	EF4	149.651	369	nd[a]	M
8/8/97	East Fork	21	EF5	149.139	374	nd	M
8/8/97	East Fork	26	EF6	149.640	370	520	M
8/8/97	East Fork	30	EF7	149.599	355	nd	M
8/8/97	East Fork	33	EF8	149.361	383	nd	M
8/8/97	East Fork	40	EF9	149.310	412	712	M
8/8/97	East Fork	53	EF10	149.230	390	nd	M
8/11/97	East Fork	61	EF11	149.171	377	555	M
8/11/97	East Fork	65	EF12	149.341	414	780	M
8/11/97	East Fork	69	EF13	149.521	403	731	M
8/11/97	East Fork	75	EF14	149.241	410	719	M
8/11/97	East Fork	78	EF15	149.210	420	865	M
8/11/97	East Fork	86	EF16	149.300	414	803	nd
	East Fork				386	647	
8/20/97	Mainstem	149	MS1	149.291	370	529	M
8/12/97	Mainstem	153	MS2	149.100	378	526	M
8/12/97	Mainstem	155	MS3	149.201	377	552	M
	Mainstem				375	536	
8/12/97	North Fork	1	NF1	149.180	362	508	M
8/20/97	North Fork	5	NF2	149.221	385	601	M
8/12/97	North Fork	9	NF3	149.620	354	463	M
8/20/97	North Fork	12	NF4	149.421	369	547	F
8/12/97	North Fork	15	NF5	149.400	368	501	M
8/20/97	North Fork	21	NF6	149.530	351	478	M
8/7/97	North Fork	22	NF7	149.541	402	nd	M
8/7/97	North Fork	22	NF8	149.109	381	nd	M
8/7/97	North Fork	24	NF9	149.611	372	nd	M
8/7/97	North Fork	24	NF10	149.590	367	nd	M
8/7/97	North Fork	24	NF11	149.510	419	797	M
8/7/97	North Fork	27	NF12	149.130	388	575	M
8/7/97	North Fork	27	NF13	149.191	364	536	F
8/7/97	North Fork	27	NF14	149.161	398	671	M
8/6/97	North Fork	42	NF15	149.630	345	395	M
	North Fork				375	552	

continued

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Date	Location	River Kilometer	Fish ID	Frequency	Length	Weight (g)	Sex
8/14/97	South Fork	7	SF1	149.661	387	605	M
8/14/97	South Fork	13	SF2	149.379	379	505	M
8/14/97	South Fork	16	SF3	149.280	387	566	M
8/14/97	South Fork	18	SF4	149.371	375	471	M
8/16/97	South Fork	23	SF5	149.471	372	491	M
8/16/97	South Fork	30	SF6	149.391	364	444	M
8/16/97	South Fork	36[b]	SF7	149.459	355	503	F
8/16/97	South Fork	41[b]	SF8	149.582	357	435	M
8/16/97	South Fork	46[b]	SF9	149.250	375	454	M
	South Fork				372	497	
8/7/97	West Fork	1	WF1	149.451	355	463	M
8/7/97	West Fork	2	WF2	149.411	385	624	M
8/7/97	West Fork	3	WF3	149.571	375	605	M
8/6/97	West Fork	12	WF4	149.260	375	nd	F
8/6/97	West Fork	13	WF5	149.321	360	nd	F
8/6/97	West Fork	16	WF6	149.490	374	612	M
8/6/97	West Fork	16	WF7	149.561	396	682	M
8/6/97	West Fork	24	WF8	149.151	352	417	M
8/6/97	West Fork	28	WF9	149.351	371	491	F
8/6/97	West Fork	28[c]	WF10	149.431	385	nd	M
8/6/97	West Fork	28[c]	WF11	149.120	355	nd	M
	West Fork				371	556	

[a] No data.

[b] Fish caught and released in Beaver Creek, a tributary entering South Fork at river kilometer 35.

[c] Fish caught and released 14 km up Frozenfoot Creek, a tributary entering West Fork at river kilometer 14.

Appendix C2.-Straight line distances (km) between successive trackings of 54 radio-tagged Arctic grayling used for mortality determinations. Chena River, 1997 and 1998. Negative numbers denote downstream movement, positive numbers upstream movement. Bold numbers denote last survey where radio tag is considered in a live fish. Bold 'x's denote fish that likely died prior to 9 Sept.

	Use for[a]												
Tag ID	OW	SP	H	9-Sep	30-Oct	23-Feb	29-Apr	20-May	1-Jun	16-Jun	29-Jun	28-Jul	Comments
EF1	N	N	N	**-20.3**	-0.8	0.5	0.3	-0.7	0.5	-0.5	0.6	ns[b]	Found tag on shore 6/29
EF2	N	N	N	**-39.6**	0.3	0.2	-0.4	0.5	-0.7	0.6	ns[c]	ns	
EF3	N	N	N	**-51.9**	0.1	-0.5	0.5	-0.7	1.5	-1.0	ns	nf	
EF4	N	N	N	**X** nf	0.0	-0.2	0.2	0.2	-0.3	-0.3	-0.3	ns	Found tag on shore 6/29
EF5	Y	Y	Y	nf	-14.4	-8.4	-11.6	-2.6	9.6	2.3	ns	**8.0**	
EF6	Y	Y	Y	nf	-1.2	-1.4	-1.6	-7.2	4.9	-5.4	ns	**13.9**	In Munson Cr 5/20 and 6/16
EF7	N	N	N	nf	**-71.8**	-0.7	0.5	0.1	-0.7	0.6	-0.3	ns	Found tag on shore, 6/18
EF8	Y	N	N	nf	nf	**-3.5**	-0.3	0.4	0.0	-0.2	ns	ns	
EF9	Y	N	N	nf	nf	**-12.2**	nf	nf	nf	nf	ns	ns	
EF10	N	N	N	**-67.5**	-0.4	0.2	-0.5	0.6	0.2	-0.3	ns	ns	
EF11	N	N	N	**X** nf	nf	-0.1	-0.2	0.0	0.2	0.3	0.4	0.8	
EF12	Y	Y	Y	nf	-2.1	1.4	0.3	-4.1	-14.7	22.1	ns	**-14.0**	
EF13	Y	Y	N	nf	0.8	-4.6	1.1	-5.0	**2.5**	-0.2	-0.7	ns	Located tag in woods 6/29
EF14	Y	Y	Y	nf	-20.7	1.1	-0.1	-2.8	5.2	1.2	ns	**16.0**	Caught tag hook and line 6/16
EF15	Y	Y	Y	nf	-8.7	-3.2	0.2	-15.7	2.1	-0.9	ns	**17.1**	
EF16	Y	Y	Y	nf	-17.4	-0.1	-0.3	-16.5	-16.5	13.8	ns	**35.3**	
MS1	N	N	N	**-26.0**	0.9	-0.7	0.1	-0.3	0.2	0.3	-0.4	ns	
MS2	N	N	N	**-2.1**	-0.3	0.7	-1.1	0.3	-0.4	2.2	ns	ns	
MS3	N	N	N	**-29.2**	0.2	-0.3	0.4	0.3	-1.0	0.4	ns	ns	
NF1	Y	Y	N	-1.5	-0.7	-6.8	0.7	8.5	**0.5**	ns	ns	ns	Tag found by angler on shore 6/5
NF2	Y	Y	Y	-0.1	-10.2	-0.3	-25.1	3.7	30.9	-0.2	ns	**-0.6**	
NF3	N	N	N	-3.7	**-3.8**	0.2	0.7	-1.0	-0.4	1.8	ns	ns	
NF4	N	N	N	**x** 0.5	-0.2	nf	-0.7	-17.7	nf	nf	ns	ns	
NF5	Y	Y	Y	-4.7	4.6	0.5	-0.3	-10.5	-0.6	0.0	3.5	**6.2**	In EF 5/20 thru 6/16

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Tag ID	Use for OW	SP	H	9-Sep	30-Oct	23-Feb	29-Apr	20-May	1-Jun	16-Jun	29-Jun	28-Jul	Comments
NF6	Y	Y	Y	-18.3	-5.3	0.7	-13.5	8.3	9.8	-0.4	ns	**0.4**	
NF7	Y	Y	Y	nf	-4.3	0.5	-0.3	6.2	0.3	-3.1	ns	**0.2**	In Monument Cr. 5/20,6/1
NF8	Y	Y	Y	nf	-51.1	-4.5	2.4	7.1	34.9	12.4	ns	**2.8**	Sampled on 5/6 at river kilometer 90
NF9	Y	Y	Y	nf	-23.3	-2.2	0.9	3.9	16.6	0.7	ns	**0.2**	
NF10	N	N	N	nf	**-3.8**	-0.4	-0.1	-0.5	1.0	-0.8	ns	ns	
NF11	N	N	N	nf	**-3.9**	-0.1	-0.6	0.3	0.3	-0.1	ns	ns	
NF12	Y	Y	Y	nf	-13.2	-0.9	2.6	5.5	3.1	3.8	ns	**-0.2**	
NF13	N	N	N	nf	**-9.7**	-0.1	-0.3	0.8	-0.3	0.3	ns	ns	
NF14	Y	Y	Y	nf	-9.7	0.8	-0.8	7.2	1.5	2.3	ns	**-1.1**	
NF15	N	N	N	**X** nf	nf	nf	-2.4	0.6	0.2	0.4	ns	ns	
SF1	N	N	N	**-4.9**	-1.2	nf	nf	nf	nf	nf	ns	ns	
SF2	N	N	N	nf	**-3.2**	0.6	-0.1	0.1	-0.2	0.1	0.2	ns	Found tag in water.
SF3	Y	N	N	nf	-0.6	**-8.2**	-0.1	-0.5	nf	0.3	ns	nf	
SF4	N	N	N	nf	-40.8	0.2	**-0.7**	0.2	1.1	0.8	nf	ns	Moved from Little Chena to MS 4/29
SF5	Y	N	Y	nf	-28.7	-1.0	nf	8.8	17.0	-0.2	ns	**4.9**	Sampled on 5/7 at river kilometer 80
SF6	N	N	N	**-22.8**	0.4	-1.3	-1.0	0.9	-1.1	0.8	ns	ns	
SF7	Y	Y	Y	nf	-11.3	-11.4	5.7	nf	17.2	0.5	ns	**-1.3**	
SF8	N	N	N	**X** nf	0.0	nf	-0.5	nf	0.6	-0.2	ns	ns	
SF9	Y	Y	Y	nf	-10.2	-3.7	3.8	nf	nf	2.6	2.3	**0.8**	
WF1	Y	Y	Y	0.4	-30.6	-6.7	7.3	-1.3	3.3	26.5	ns	**1.2**	In SF 10/30 and 5/20.
WF2	N	Y	N	nf	nf	nf	-65.5	17.0	39.7	**17.4**	ns	nf	Sampled on 4/29 at river kilometer
WF3	Y	Y	Y	nf	-3.9	0.9	2.6	3.3	0.3	-0.3	ns	**-3.4**	In NF above WF 4/29 thru 6/16
WF4	N	N	N	nf	**-4.7**	-0.3	0.9	-1.9	-0.9	-0.1	ns	ns	
WF5	Y	Y	Y	nf	-26.9	-0.9	0.0	-7.2	18.3	8.7	ns	**6.8**	
WF6	Y	Y	Y	-7.9	-0.5	0.3	0.4	6.1	1.0	-4.5	ns	**4.3**	In Monument Cr. 5/20 thru 6/1
WF7	N	N	N	nf	**-5.2**	0.1	-0.6	-0.3	0.7	-0.6	ns	ns	
WF8	N	N	N	**X** nf	nf	nf	nf	nf	nf	nf	ns	ns	

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	Use for												
Tag ID	OW	SP	H	9-Sep	30-Oct	23-Feb	29-Apr	20-May	1-Jun	16-Jun	29-Jun	28-Jul	Comments
WF9	N	N	N	nf	**-11.6**	-0.7	nf	nf	nf	nf	ns	ns	
WF10	Y	Y	Y	nf	-15.1	1.5	-0.5	12.1	1.6	-0.4	ns	**1.6**	
WF11	Y	Y	Y	nf	-13.8	0.2	-0.7	9.1	5.1	0.8	ns	**0.5**	

[a] Fish used for determination of OW = overwintering area; SP = spawning area; H = homing area. Y = yes; N = no.

[b] ns = tag not searched for.

[c] nf = tag not found.

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Appendix C3.-Locations of 30 Arctic grayling implanted with radio transmitters by area and river kilometer in the Chena River drainage, 1997 to 1998. Blocked locations denote the date used for spawning area determinations.

At release				9 Sept		30 Oct		23 Feb		29 Apr		20 May		1 Jun		16 Jun		28 Jul	
Date	Fish #	km	Loc[a]	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc
8/8/97	EF5	21	EF	---	nf[b]	155	MS	144	MSA	125	MSA	120	MSA	137	MSA	141	MSA	152	MS
8/8/97	EF6	26	EF	---	nf	24	EF	26	EF	24	EF	10	EFM	19	EF	10	EFM	32	EF
8/8/97	EF8	33	EF	---	nf	---	na[c]	29	EF	---	D[d]	---	D	---	D	---	D	---	D
8/8/97	EF9	40	EF	---	nf	---	na	138	MSA	---	D	---	D	---	D	---	D	---	D
8/11/97	EF12	65	EF	---	nf	62	EF	64	EF	64	EF	60	EF	40	EF	69	EF	52	EF
8/11/97	EF13	69	EF	---	nf	---	na	64	EF	---	na	---	na	62	EF	---	D	---	D
8/11/97	EF14	75	EF	---	nf	50	EF	51	EF	52	EF	48	EF	54	EF	56	EF	74	EF
8/11/97	EF15	78	EF	---	nf	68	EF	64	EF	64	EF	45	EF	48	EF	47	EF	68	EF
8/11/97	EF16	86	EF	---	nf	64	EF	64	EF	64	EF	44	EF	20	EF	39	EF	84	EF
8/12/97	NF1	1	NF	155	MS	154	MS	146	MS	146	MS	2	NF	1	NF				
8/20/97	NF2	5	NF	5	NF	145	MS	145	MS	102	MSA	108	MSA	5	NF	4	NF	5	NF
8/12/97	NF5	16	NF	10	NF	16	NF	16	NF	16	NF	3	EF	3	EF	3	EF	10	NF
8/20/97	NF6	21	NF	151	MS	143	MSA	144	MSA	122	MSA	136	MSA	151	MS	151	MS	150	MS
8/7/97	NF7	22	NF	---	nf	16	NF	17	NF	16	NF	2	NFM	3	NFM	22	NF	22	NF
8/7/97	NF8	22	NF	---	nf	89	MSA	81	MSA	86	MSA	99	MSA	0	NF	18	NF	22	NF
8/7/97	NF9	24	NF	---	nf	147	MS	144	MSA	146	MS	150	MS	18	NF	19	NF	20	NF
8/7/97	NF12	27	NF	---	nf	10	NF	9	NF	12	NF	20	NF	23	NF	27	NF	28	NF
8/7/97	NF14	27	NF	---	nf	16	NF	16	NF	16	NF	24	NF	26	NF	28	NF	28	NF
8/14/97	SF3	16	SF	---	nf	---	nf	121	MSA	---	D	---	D	---	D	---	D	---	D
8/14/97	SF4	18	SF	---	nf	39	MSL	39	MSL	41	MSA	---	D	---	D	---	D	---	D
8/16/97	SF5	22	SF	---	nf	92	MSA	82	MSA	82	MSA	97	MSA	8	SF	8	SF	17	SF
8/16/97	SF7	36	SFB	---	nf	15	SF	113	MSA	123	MS	---	nf	36	SFB	37	SF	36	SFB
8/16/97	SF9	46	SFB	---	nf	27	SF	22	SF	28	SF	---	nf	---	nf	33	SF	38	SF
8/7/97	WF1	1	WF	2	WF	2	SF	113	MSA	126	MSA	2	SF	130	MSA	0	WF	20	NF
8/7/97	WF2	2	WF	---	nf	---	nf	---	nf	34	MSA	85	MSA	152	MS	4	WF	---	nf
8/7/97	WF3	3	WF	---	nf	15	NF	16	NF	20	NF	23	NF	23	NF	23	NF	2	WF

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At release				9 Sept		30 Oct		23 Feb		29 Apr		20 May		1 Jun		16 Jun		28 Jul	
Date	Fish #	km	Loc[a]	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc	km	Loc
8/6/97	WF5	13	WF	---	nf	148	MS	147	MS	---	nf	135	MSA	10	NF	4	WF	13	WF
8/6/97	WF6	16	WF	16	NF	16	NF	16	NF	16	NF	0	NFM	1	NFM	19	NF	6	WF
8/6/97	WF10	14	WFF	---	nf	6	WF	8	WF	8	WF	11	FF	14	FF	14	FF	15	FF
8/6/97	WF11	14	WFF	---	nf	8	WF	8	WF	8	WF	6	FF	14	FF	14	FF	14	FF

[a] Loc = location: EF = East Fork; EFM = Munson Cr., tributary to EF; NF = North Fork; NFM = Monument Cr., tributary to NF; SF = South Fork; WF = West Fork; MS = Mainstem river kilometer 145 - 156; MSA = assessed area of the mainstem river kilometer 0 – 144; MSL = Little Chena at 39 km MSA.

[b] nf = tag not found.

[c] na = not available.

[d] D = Dead.

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Appendix C4.-Overwintering locations and distances from release sites of 29 radio-tagged Arctic grayling in the Chena River drainage, 1997 and 1998. Negative numbers denote downstream movement, positive numbers upstream movement.

At release				23-Feb		
Date	Fish #	River Kilometer	Loc	River Kilometer	Loc	Distance Moved
8/8/97	EF5	21	EF	144	MSA	-33
8/8/97	EF6	26	EF	26	EF	0
8/8/97	EF8	33	EF	29	EF	-4
8/8/97	EF9	40	EF	138	MSA	-58
8/11/97	EF12	65	EF	64	EF	-1
8/11/97	EF13	69	EF	64	EF	-5
8/11/97	EF14	75	EF	51	EF	-24
8/11/97	EF15	78	EF	64	EF	-14
8/11/97	EF16	86	EF	64	EF	-22
8/12/97	NF1	1	NF	146	MS	-11
8/20/97	NF2	5	NF	145	MS	-16
8/12/97	NF5	16	NF	16	NF	0
8/20/97	NF6	21	NF	144	MSA	-33
8/7/97	NF7	22	NF	17	NF	-5
8/7/97	NF8	22	NF	81	MSA	-97
8/7/97	NF9	24	NF	144	MSA	-35
8/7/97	NF12	27	NF	9	NF	-18
8/7/97	NF14	27	NF	16	NF	-11
8/14/97	SF3	16	SF	138	MSA	-19
8/6/97	SF4	18	SF	2	LCR	-104
8/16/97	SF5	22	SF	82	MSA	-65
8/16/97	SF7	36	SFB	113	MSA	-48
8/16/97	SF9	46	SF	28	SF	-18
8/7/97	WF1	1	WF	113	MSA	-62
8/7/97	WF3	3	WF	16	NF	-5
8/6/97	WF5	13	WF	147	MS	-40
8/6/97	WF6	16	WF	16	NF	-18
8/6/97	WF10	14	WFF	8	WF	-6
8/6/97	WF11	14	WFF	8	WF	-6

[a] Loc = location: EF = East Fork; EFM = Munson Cr.,tributary to EF; NF = North Fork; NFM = Monument Cr., tributary to NF; SF = South Fork; SFB = Beaver Creek, a tributary to South Fork; WF = West Fork; WFF = Frozenfoot Creek, a tributary to West Fork; MSA = Mainstem from km 0 – km 144; MS = Mainstem from km 145 – 156; LCR = Little Chena River.

Appendix C5.-Data summary of catch from electrofishing the lower 138 km of the Chena River, 29 April through 9 May 1998.

							Females								
		Catch					Green			Ripe			Spent		
Date	km	Total	Males	Females	Unknowns	M:F	n	p	SE	n	p	SE	n	p	SE
4/30-5/1	0-24	233	144	43	46	3.3	36	0.84	0.02	5	0.12	0.03	0	0.00	0.00
4/29-30	24-40	356	207	64	85	3.2	59	0.92	0.01	9	0.14	0.03	0	0.00	0.00
5/4-5	40-56	528	326	112	90	2.9	61	0.54	0.02	37	0.33	0.05	13	0.12	0.05
5/4	56-72	256	132	56	68	2.4	43	0.77	0.02	13	0.23	0.04	0	0.00	0.00
5/7-8	72-90	301	134	77	90	0.9	43	0.56	0.02	23	0.30	0.04	11	0.14	0.06
5/6	90-107	130	67	19	44	0.4	13	0.68	0.02	5	0.26	0.04	1	0.05	0.04
5/8	107-125	335	81	71	183	0.4	53	0.75	0.02	14	0.20	0.04	3	0.04	0.03
5/8-9	125-138	492	191	184	117	1.6	168	0.91	0.01	3	0.02	0.01	8	0.04	0.03
Totals	0-138	2,631	1,282	626	723	1.6	476	0.76	0.02	109	0.17	0.04	36	0.06	0.04

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Appendix C6.-Spawning locations and distances from release and overwintering sites of 27 radio-tagged Arctic grayling in the Chena River drainage, 1997 and 1998. Negative distances denote downstream direction, positive numbers upstream movement.

At release				At Spawning			Distance (km) from	
Date	Fish #	km	Loc[a]	Date	km	Loc	Release	Overwintering
8/8/97	EF5	21	EF	29-Apr	125	MSA	-52	-19
8/8/97	EF6	26	EF	20-May	10	EFM	-21	-22
8/11/97	EF12	65	EF	1-Jun	40	EF	-25	-24
8/11/97	EF13	69	EF	1-Jun	62	EF	-7	-2
8/11/97	EF14	75	EF	1-Jun	54	EF	-21	-3
8/11/97	EF15	78	EF	1-Jun	48	EF	-31	-16
8/11/97	EF16	86	EF	1-Jun	20	EF	-66	-44
8/12/97	NF1	1	NF	20-May	2	NF	0	12
8/20/97	NF2	5	NF	29-Apr	102	MSA	-59	-43
8/12/97	NF5	16	NF	20-May	3	EF	-19	-19
8/20/97	NF6	21	NF	29-Apr	122	MSA	-55	-23
8/7/97	NF7	22	NF	20-May	2	NFM	4	8
8/7/97	NF8	22	NF	29-Apr	86	MSA	-92	5
8/7/97	NF9	24	NF	20-May	150	MS	-29	6
8/7/97	NF12	27	NF	1-Jun	20	NF	-4	14
8/7/97	NF14	27	NF	1-Jun	26	NF	-1	10
8/14/97	SF4	18	SF	29-Apr	41	MSA	-100	4
8/16/97	SF5	22	SF	29-Apr	82	MSA	-65	0
8/16/97	SF7	36	SFB	29-Apr	123	MSA	-38	10
8/16/97	SF9	46	SF	29-Apr	28	SF	-18	6
8/7/97	WF1	1	WF	29-Apr	126	MSA	-50	13
8/7/97	WF2	2	WF	29-Apr	34	MSA	-140	nf[b]
8/7/97	WF3	3	WF	20-May	23	NF	9	7
8/6/97	WF5	13	WF	20-May	135	MSA	-39	-12
8/6/97	WF6	16	WF	20-May	0	NFM	22	8
8/6/97	WF10	14	WFF	20-May	11	WFF	-3	17
8/6/97	WF11	14	WFF	20-May	6	WFF	-8	17

[a] Loc = location: EF = East Fork; EFM = Munson Cr.,tributary to EF; NF = North Fork; NFM = Monument Cr., tributary to NF;SF = South Fork; SFB = Beaver Creek, a tributary to South Fork; WF = West Fork; WFF = Frozenfoot Creek, a tributary to West Fork; MSA = Mainstem from km 0 – km 144; MS = Mainstem from km 145 - 156.

[b] nf = Tag not found during survey.

Appendix C7.-Difference in kilometers between release site in August 1997 and 28 July 1998 tracking location of 23 radio-tagged Arctic grayling in the Chena River drainage. Negative distances denote downstream direction, positive numbers upstream movement.

At release August 1997				28-July 1998		
Date	Fish#	km	Loc[a]	km	Loc	Difference
8/8/97	EF5	21	EF	152	MS	-25
8/8/97	EF6	26	EF	32	EF	6
8/11/97	EF12	65	EF	52	EF	-13
8/11/97	EF14	75	EF	74	EF	0
8/11/97	EF15	78	EF	68	EF	-10
8/11/97	EF16	86	EF	84	EF	-3
8/20/97	NF2	5	NF	5	NF	0
8/12/97	NF5	16	NF	10	NF	-5
8/20/97	NF6	21	NF	150	MS	-27
8/7/97	NF7	22	NF	22	NF	0
8/7/97	NF8	22	NF	22	NF	0
8/7/97	NF9	24	NF	20	NF	-4
8/7/97	NF12	27	NF	28	NF	1
8/7/97	NF14	27	NF	28	NF	0
8/16/97	SF5	22	SF	17	SF	-5
8/16/97	SF7	36	SFB	36	SFB	0
8/16/97	SF9	46	SFB	38	SFB	-8
8/7/97	WF1	1	WF	20	NF	3
8/7/97	WF3	3	WF	2	WF	-2
8/6/97	WF5	13	WF	13	WF	0
8/6/97	WF6	16	WF	6	WF	-10
8/6/97	WF10	14	WFF	15	WFF	1
8/6/97	WF11	14	WFF	14	WFF	0

[a] Loc = location: EF = East Fork; NF = North Fork; SF = South Fork; SFB = Beaver Creek, a tributary to South Fork; WF = West Fork; WFF = Frozenfoot Creek, a tributary to West Fork; MS = Mainstem.

Appendix C8.-Comparison of catches between July 1997 and May 1998 in the lower 144 km of the Chena River.

May-98	Total			150-269 mm			≥270 mm			≥350 mm		
river kilometer	n	p	SE	n	p	SE	n	p	SE	n	p	SE
0-24	231	0.09	0.01	60	0.26	0.02	171	0.74	0.01	12	0.03	0.01
24-40	356	0.14	0.01	112	0.31	0.02	244	0.69	0.01	21	0.05	0.01
40-56	528	0.20	0.01	87	0.16	0.02	441	0.84	0.01	113	0.26	0.02
56-72	251	0.10	0.01	46	0.18	0.02	205	0.82	0.01	56	0.13	0.02
72-90	300	0.11	0.01	59	0.20	0.02	241	0.80	0.01	78	0.18	0.02
90-107	130	0.05	0.00	19	0.15	0.02	111	0.85	0.01	38	0.09	0.01
107-125	334	0.13	0.01	89	0.27	0.02	245	0.73	0.01	37	0.09	0.01
125-138	490	0.19	0.01	24	0.05	0.01	466	0.95	0.00	79	0.18	0.02
Totals	2620	1.00		496	0.19		2124	0.81		434		

July 1998	Total			150-269 mm			≥270 mm			≥350 mm		
river kilometer	n	p	SE	n	p	SE	n	p	SE	n	p	SE
0-24	67	0.05	0.01	56	0.98	0.00	1	0.02	0.01	0	0.00	0.00
24-40	314	0.22	0.01	259	0.82	0.01	55	0.18	0.02	0	0.00	0.00
40-56	155	0.11	0.01	105	0.68	0.02	50	0.32	0.02	1	0.04	0.04
56-72	146	0.10	0.01	92	0.63	0.02	54	0.37	0.02	3	0.12	0.06
72-90	134	0.10	0.01	66	0.49	0.02	68	0.51	0.02	3	0.12	0.06
90-107	175	0.12	0.01	65	0.37	0.02	110	0.63	0.02	6	0.23	0.08
107-125	197	0.14	0.01	110	0.56	0.02	87	0.44	0.02	6	0.23	0.08
125-138	217	0.15	0.01	111	0.51	0.02	106	0.49	0.02	7	0.27	0.09
Totals	1405	1.00		864	0.62		531	0.38		26		

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Appendix D

Appendix D.-Evaluation of the Stock Assessment Program for Chena River Arctic Grayling by Michael Wallendorf.

Task 3 of the 1996 and 1997 operational plans for stock assessment of Arctic grayling in the Chena River reads as "evaluate the stock assessment program in the Chena River in relation to fiscal and biological efficiency." The current design for stock assessment is a mark-recapture (MR) survey on the lower 152 km. Perhaps a survey on a smaller area of the river would track the population at a lower cost with precision that meets our objectives.

To reduce the sampling effort in future surveys, a simple random sample of r 10 mile units can be taken from the 8 units available between river miles 10 and 90. The effect of reduced effort will be a reduction in precision. We can use data from past surveys to estimate population size for each unit, then assess how much precision a sample of units would provide for the expanded total population estimate. Estimates can be made with the following equations:

$$\hat{N} = R\hat{\bar{N}} \qquad \text{(D1)}$$

$\hat{N} =$ the estimate population size between river miles 10 and 90,

R = the number of sample units available,

$$\hat{\bar{N}} = \frac{\sum_j^r \hat{N}_j}{r},$$

r = sample size for a simple random sample from the R sample units, and

$\hat{N}_j$ = mark-recapture abundance estimate in unit j.

Variance of $\hat{N}$ can be estimated by the following equation (Clark and Ridder 1988, Cochran 1977)

$$\hat{V}(\hat{N}) = \left[R^2\left(\frac{R-r}{R}\right)\frac{s^2}{r}\right] + \left[\frac{R^2}{r^2}\sum_j^r \hat{V}\left(\hat{N}_j\right)\right], \qquad \text{(D2)}$$

where $s^2 = \frac{\sum_j^r\left(\hat{N}_j - \hat{\bar{N}}\right)^2}{r-1}$ and $\hat{V}\left(\hat{N}_j\right)$ is the estimated variance for the population estimate of the jth sample unit. The first term of equation 2 estimates between unit variation and the second term estimates within unit variation. The fraction $\frac{R-r}{R}$ is the finite population correction factor. If $r = R$, then the estimates $\hat{N}$ and $\hat{V}\left(\hat{N}\right)$ are the same as that of a fully stratified survey without sampling among units (Cochran 1977, page 279). Assume that the expected within unit variance is equal among all R units. This expectation can be estimated by

$$\bar{V}\left(\hat{N}_.\right) = \frac{\sum_j^R \hat{V}\left(\hat{N}_j\right)}{R}.$$

Likewise, the between unit variance for all units can be estimated by (Cochran 1977, page 23).

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$$S^2 = \frac{\sum_i^R \left(\hat{N}_i - \hat{\bar{N}}\right)^2}{R-1}$$

where $\hat{\bar{N}}$ is the mean of the population estimates of all R units. With data from all units, we can evaluate $V\left(\hat{N}\right)$ at different values of r by the equation

$$V\left(\hat{N}\right) = \left[R^2\left(\frac{R-r}{R}\right)\frac{S^2}{r}\right] + \left[\frac{R^2}{r^2} r\overline{V}\left(\hat{N}_.\right)\right]$$

$$= \frac{R^2}{r}\left\{\left(\frac{R-r}{R}\right)S^2 + \overline{V}\left(\hat{N}_.\right)\right\}. \qquad \text{(D3)}$$

This will tell us the impact on precision by a reduction in sample size.

Mark-recapture data from 1992 through 1996 were grouped to represent 10 mile units from river mile 10 to 90 in the Chena River. These data were not broken down by fish length and did not describe movement of recaptured fish (some marked fish may have moved across unit boundaries). The objective for stock assessment has been to estimate N such that the true N is within 25% of the estimate 95% of the time. This corresponds to a coefficient of variation (cv) of 0.13. The cv's listed in Table D1 are calculated from equations 1 and 3.

Table D1.-Coefficient of variation (cv) for population size estimates from 1992 through 1996 with reduced sample sizes.

	1992	1993	1994	1995	1996
Sample Size			cv		
4	0.165	0.192	0.173	0.126	0.206
5	0.135	0.155	0.140	0.107	0.169
6	0.111	0.125	0.112	0.092	0.138
7	0.089	0.097	0.086	0.079	0.112
8	0.069	0.070	0.060	0.069	0.086
$\hat{N}^*$	23905	61827	80035	40239	37905
S^2	1283827	12831900	18280218	1319856	4946892
$\overline{V}(\hat{N}_.)$	336519	2362499	2898863	950184	1343624
$\hat{N}^+$	29300	72700	90000	45100	42800
SE	2300	5800	5900	4400	4200
cv	0.078	0.080	0.066	0.098	0.097

* N estimated from all sample areas from river mile 10 to 90 with no correction for size selectivity or movement.

+ N estimated (wild & enhancement fish) with correction for size selectivity as reported in previous reports (Ridder and Fleming 1997, Clark 1996, Clark 1995, Clark 1994, Clark 1993).

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In Table D1, the stratified estimates from all 8 sample units in river miles 10 through 90 are smaller than the reported estimates. In part, this is due to the sample area being smaller (i.e. the lower 10 miles are not included). Also, bias from size selectivity or movement may be present. Even with this difference, the estimates are reasonable. The sample size providing a cv of 0.13 is 6 units of 10 miles each. However, in 1996, a random sample of 6 units would not have provided sufficient precision to meet our objectives.

Table D2 shows that many marked fish move out of the sample unit where they were marked. Notice that fish moved upstream and downstream from unit 7; one fish moved over 20 mi downstream. Some extra sampling above and below isolated sample units during the second event may be necessary to avoid bias due to emigration of marked fish. These data could be analyzed with a model for geographic stratification (Darroch 1961). Floy tagging during the mark event would be necessary to track recapture movements (currently fish are marked with fin clips only). The extra work would compromise the cost savings of reducing the sample size from the 8 units currently sampled to 6 units.

Table D2.-Mark and recapture locations of the 1993 recaptured fish.

	recapture							
	1	2	3	4	5	6	7	8
mark 1	52	10	0	0	0	0	0	0
2	0	42	9	1	0	0	0	0
3	0	1	49	7	0	0	0	0
4	0	0	4	36	1	0	0	0
5	0	0	0	1	19	0	0	0
6	0	0	0	0	1	11	2	0
7	0	0	0	1	0	7	23	1
8	0	0	0	0	0	0	2	25

One advantage of reducing sampling effort is the opportunity to use more research resources in tributaries of the Chena River. These studies have the potential of providing a more full understanding of how the Chena River population works. However, if we reduce precision in the lower river, the inferences about recruitment or movement into upstream reaches may be compromised. When studies are done beyond the current assessed area, a strong survey in the lower river is needed to provide a complete picture of the Chena River population.