Fishery Data Series No. 08-50

Stock Assessment of Rainbow Trout in the Wood River Lakes System, 2003-2005

by

Jason E. Dye

October 2008

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

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

FISHERY DATA SERIES NO. 08-50

STOCK ASSESSMENT OF RAINBOW TROUT IN THE WOOD RIVER LAKES SYSTEM, 2003-2005

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October 2008

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-19 and F-10-20, Job No. R-2-14.

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

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This document should be cited as:
Dye, J. E. 2008. Stock assessment of rainbow trout in the Wood River Lakes System, 2003-2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-50, Anchorage.

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ABSTRACT

During 2003, tracking of radio-tagged rainbow trout indicated that at least 47% of the fish tagged in the Agulowak River remained in the upper stretches of the Agulowak River (River Bay) throughout the winter and at least 53% of the fish tagged in the Agulukpak River remained in the Agulukpak River throughout the winter. Radio-tagged fish were located in 18 tributaries of the Wood River lakes system during late April through May (including the Agulowak and Agulukpak), of which 12 were within the survey area. Further on-site sampling documented fish spawning in 8 of these 12 tributaries. Moose Creek, a tributary of Lake Beverley, was identified as the most suitable spawning tributary for phase-2 investigations. Rainbow trout ≥300 mm fork length were sampled for length during 2003; 531 and 291 were sampled from the Agulowak and Agulukpak rivers, respectively. In the Agulowak River the average fork length of sampled rainbow trout was 393 mm with a range of 300-620 mm. In the Agulukpak River the average fork length of sampled rainbow trout was 482 mm with a range of 302-690 mm. The length distribution of the first 50% of fish sampled during 2003 was not significantly different from the second 50% of fish sampled in either the Agulowak River (P=0.304) or Agulukpak River (P=0.073).

For phase-2 investigations a weir was installed in Moose Creek on May 22 after multiple delays due to ice and high water conditions. A total of 145 rainbow trout were captured at the weir at Moose Creek between May 15 and June 17, 2005. Upstream captures of rainbow trout totaled 14 and downstream captures totaled 131. Of the 14 fish tagged in the upstream weir trap, 4 were recaptured later in the downstream trap. An unknown number of rainbow trout remained above the weir and were not counted when the weir was removed. Therefore, it can be concluded from the 2005 weir count that the abundance of rainbow trout in Moose Creek exceeded 145 during 2005. A total of 171 rainbow trout with a fork length ≥300 mm were sampled in May and June 2005. The average fork length of these fish was 508 mm with a range of 301-660 mm. The length distribution of the first 50% of fish sampled during 2005 was significantly smaller than the second 50% of fish sampled during the sampling period in Moose Creek (P<0.001).

INTRODUCTION

Rainbow trout *Oncorhynchus mykiss* are an important sport fish in southwest Alaska (Mills 1982-1994; Howe et al. 1995, 1996, 2001 a-d; Walker et al. 2003, and Jennings et al. 2004). Since statehood, the Alaska Department of Fish and Game (ADF&G) has conducted studies of rainbow trout to document stock status and life history. Currently, management is directed by the Southwest Alaska Rainbow Trout Management Plan[1] adopted by the Alaska Board of Fisheries (BOF) in February 1990. The overriding philosophy of this plan is conservative wild stock management to maintain historical size and age compositions.

The Wood River lakes in southwestern Alaska (Figure 1) are an extremely popular destination for rainbow trout anglers. Currently there are approximately 15 sport lodges using the system, five of which first began operation after 1998. Several individual Native Allotments are in the process of being conveyed to individuals in 160-acre or smaller parcels. Many of the recent conveyances are being subdivided and sold, increasing opportunities for recreational property development by private individuals. Long-time private anglers have complained of increased competition with guided anglers for angling sites on tributaries formerly unused by guided anglers. The Agulowak and Agulukpak are relatively short, easily accessible rivers that support the largest aggregation of rainbow trout and the highest levels of sport fishing effort in the Wood River lakes system. The Agulukpak River rainbow trout fishery is the only river in the Wood River lakes system managed as a special management area requiring catch and release as well as only allowing fly-fishing (Dunaway and Sonnichsen 2001). Since 1990, the Agulowak River

[1] ADF&G. *Unpublished*. Southwest Alaska rainbow trout management plan. Prepared for the Alaska Board of Fisheries, February 1990. Alaska Department of Fish and Game, Division of Sport Fish, Anchorage. http://www.sf.adfg.state.ak.us/region1/trout/wildtrout/rbtmgt1990bof_1.pdf

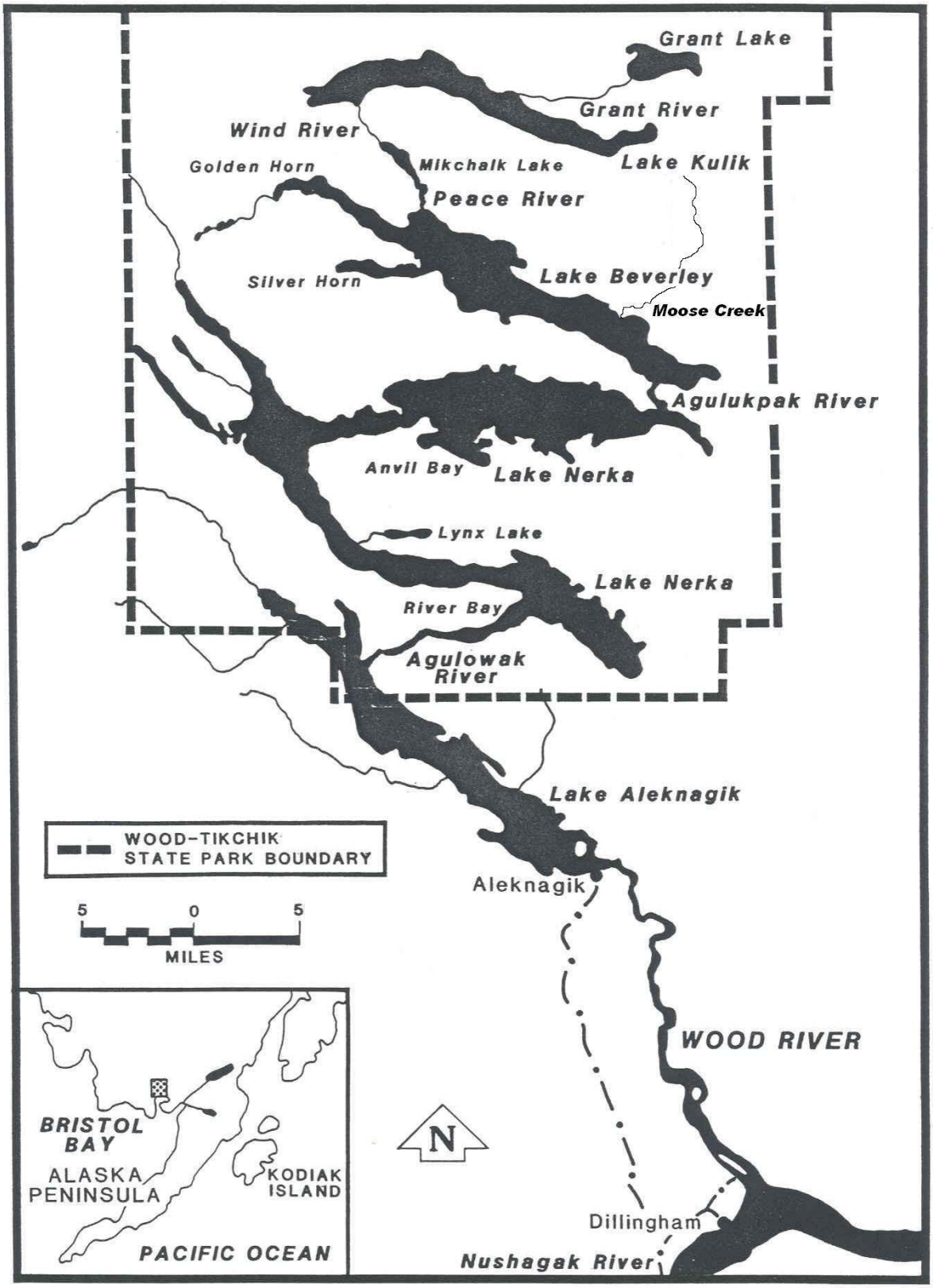

Figure 1.-Wood River lakes system.

rainbow trout fishery has been limited to single-hook artificial lures and a daily bag limit of one fish (Dunaway and Sonnichsen 2001). None of the waters in the Wood River drainage are currently protected by a spawning season closure. During 1992, an abundance estimate of rainbow trout in the Agulukpak and Agulowak rivers conducted by ADF&G indicated these rivers had one of the densest populations of healthy rainbow trout in Alaska (Dunaway 1993). During 1996, size composition information collected from rainbow trout in the Agulukpak River was found to be similar to the historic size composition (Rogan and Jaenicke 1997). However, ADF&G does not currently have specific information on the life history, population dynamics, or locations of critical habitat areas used by Wood River lakes rainbow trout.

This project included two phases and will allow ADF&G to develop a long-term rainbow trout database and identify factors limiting rainbow trout production in the Wood River lakes system. Phase one of the project involved identifying critical habitat areas used by rainbow trout feeding in the Agulowak and Agulukpak rivers during August and September. Phase two involved measurement of abundance, size composition, and sexual maturity of the rainbow trout spawning population in Moose Creek. In addition, the information collected will be used to evaluate and update policies in the Southwest Alaska Rainbow Trout Management Plan.

OBJECTIVES

Phase 1

1. Detect with 95% confidence, the 13 most important streams which together receive at least 75% of the sexually mature (>450 mm) rainbow trout that feed in the Agulowak and Agulukpak rivers during August and September 2003.
2. Estimate length composition of rainbow trout ≥300 mm fork length (FL) in each of the Agulowak and Agulukpak rivers during August and September 2003 such that the estimated proportions are within 10 percentage points of the actual values 95% of the time.

Phase 2

1. Enumerate the spawning population of rainbow trout in Moose Creek during April 15 through June 10, 2005; and
2. Measure the length and sexual maturity composition of rainbow trout in Moose Creek during April 15 through June 10, 2005.

TASKS

Phase 1

1. Identify important feeding and overwintering areas for rainbow trout captured in the Agulowak and Agulukpak rivers during August and September 2003 by surgically implanting high frequency radio transmitters and tracking movements of radio-tagged fish;
2. Rank the importance of spawning locations according to radio transmitter recoveries;
3. Inject a Passive Integrated Transponder (PIT)[2] tag into all rainbow trout captured during the study;

[2] A Passive Integrated Transponder tag is a radio frequency device that transmits a unique individual code to a reader where it is displayed in a numeric or alphanumeric form.

4. Collect genetic samples from all rainbow trout >300 mm FL captured in the Agulowak and Agulukpak rivers during August and September 2003; and
5. Compare long-term survival (i.e. through study period) between rainbow trout anesthetized with clove oil and those anesthetized with spearmint oil.

Phase 2

1. Document the number and proportion of unmarked rainbow trout captured upstream of the weir site during April 15 through June 10, 2005;
2. Tag all rainbow trout ≥250 mm FL passing through a weir on Moose Creek;
3. Check all rainbow trout passing through a weir on Moose Creek for tags and secondary marks;
4. Enumerate and record all other fish species immigrating and emigrating at Moose Creek during April 15 through June 10, 2005;
5. Collect length information from all other fish species captured in Moose Creek during April 15 through June 10, 2005;
6. Document rainbow trout spawning locations in Moose Creek during April 15 through June 10, 2005; and
7. Collect daily water temperature readings at Moose Creek during April 15 through June 10, 2005.

METHODS

This project was conducted in two phases. The first phase had two primary study areas where rainbow trout were captured, sampled, and radiotagged. One study area was a 3.2 mile reach of Agulowak River between the outlet of Lake Nerka at River Bay on the east and Conquest's cabin above the confluence with Lake Aleknagik on the west (Figure 2). The second study area was a 3.5 mile reach of Agulukpak River between the outlet of Lake Beverley on the north and the confluence of Lake Nerka on the south (Figure 3). This portion of the study also included a larger aerial and/or boat survey area in which radio-tagged fish were monitored and tracked on a regular basis. The aerial and/or boat survey area included lakes Beverley and Nerka and all of their tributaries and the Agulukpak and Agulowak rivers. Radio-tagged fish which strayed outside the survey area were tracked and/or located on an opportunistic basis (e.g., as time, money, manpower, and weather allowed). This phase provided locations of spawning rainbow trout that fed in the Agulowak and Agulukpak rivers during August and September of 2003. The first phase revealed Moose Creek, a tributary that flows into Lake Beverley, as a suitable spawning area to study more intensively (Figure 4). For the second phase of the study a bi-directional weir was installed on Moose Creek (Figure 5) approximately 300 meters upstream from its confluence with Lake Beverley to conduct long-term population investigations.

PHASE 1

Detection of Spawning, Feeding, and Overwintering Areas

During August and September of 2003, hook and line sampling was employed to capture rainbow trout while the fish were in major feeding aggregations in the Agulowak and Agulukpak rivers. Sixty mature rainbow trout ≥450 mm FL in each drainage (120 total) were surgically

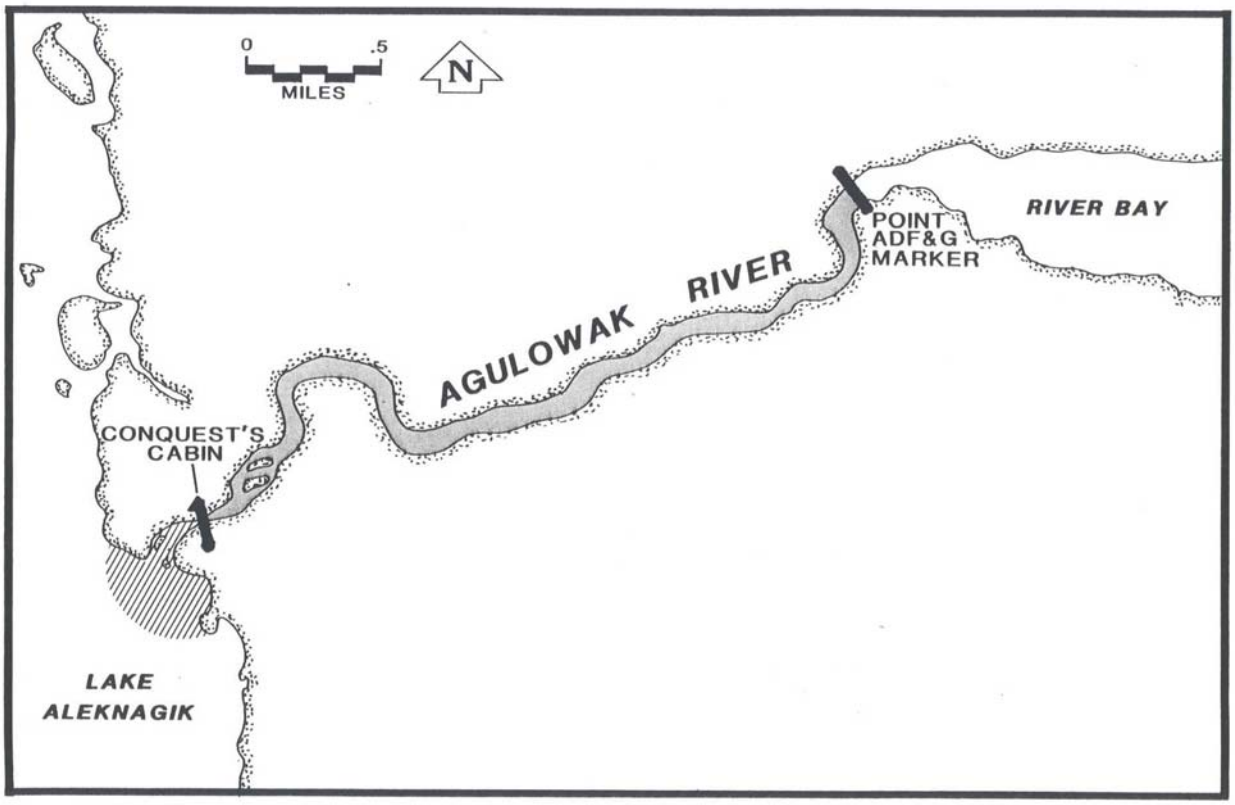

Figure 2.-Agulowak River study site.

implanted with Advanced Telemetry Systems (ATS) Model F1835 internal implant high frequency radio transmitters with a programmed signal life of 12 months. Each tag weighed a recommended 13 g, which is approximately 2% of the body weight of a rainbow trout 450 mm FL. To identify mortalities, each tag was equipped with a mortality switch that increased the pulse rate of transmissions after a tag was stationary for a period of 8 continuous hours. Tags were implanted following procedures in Hart and Summerfelt (1975).

Following insertion of a radio transmitter and/or PIT tag into a rainbow trout, release date, global positioning system (GPS) coordinates, length, transmitter frequency of implanted radio tag, PIT tag number, sex, anesthetic used and any other comments were recorded on a radio-tagging form. PIT tagging was conducted using established U.S. Fish and Wildlife Service (USFWS) procedures (Nick Hetrick, Fishery Biologist, USFWS, King Salmon; personal communication).

Each day, the technicians tallied the number of rainbow trout captured, the number of new tags deployed, the number of tagged fish recaptured, the number of mortalities, the number of fish released with tags, hours worked, and any equipment problems. These daily tallies were used to track project performance inseason, and to keep a running tally of the number of tags deployed and recovered on a daily basis. At the end of the study period, all tagging data were transferred to a Microsoft (MS) Excel spreadsheet.

Movements of radio-tagged fish were monitored for an entire calendar year by periodic aerial and boat surveys and by fixed tracking stations at both the inlet and outlet of the rivers. Aerial and/or boat surveys were conducted weekly during April and May and monthly during the

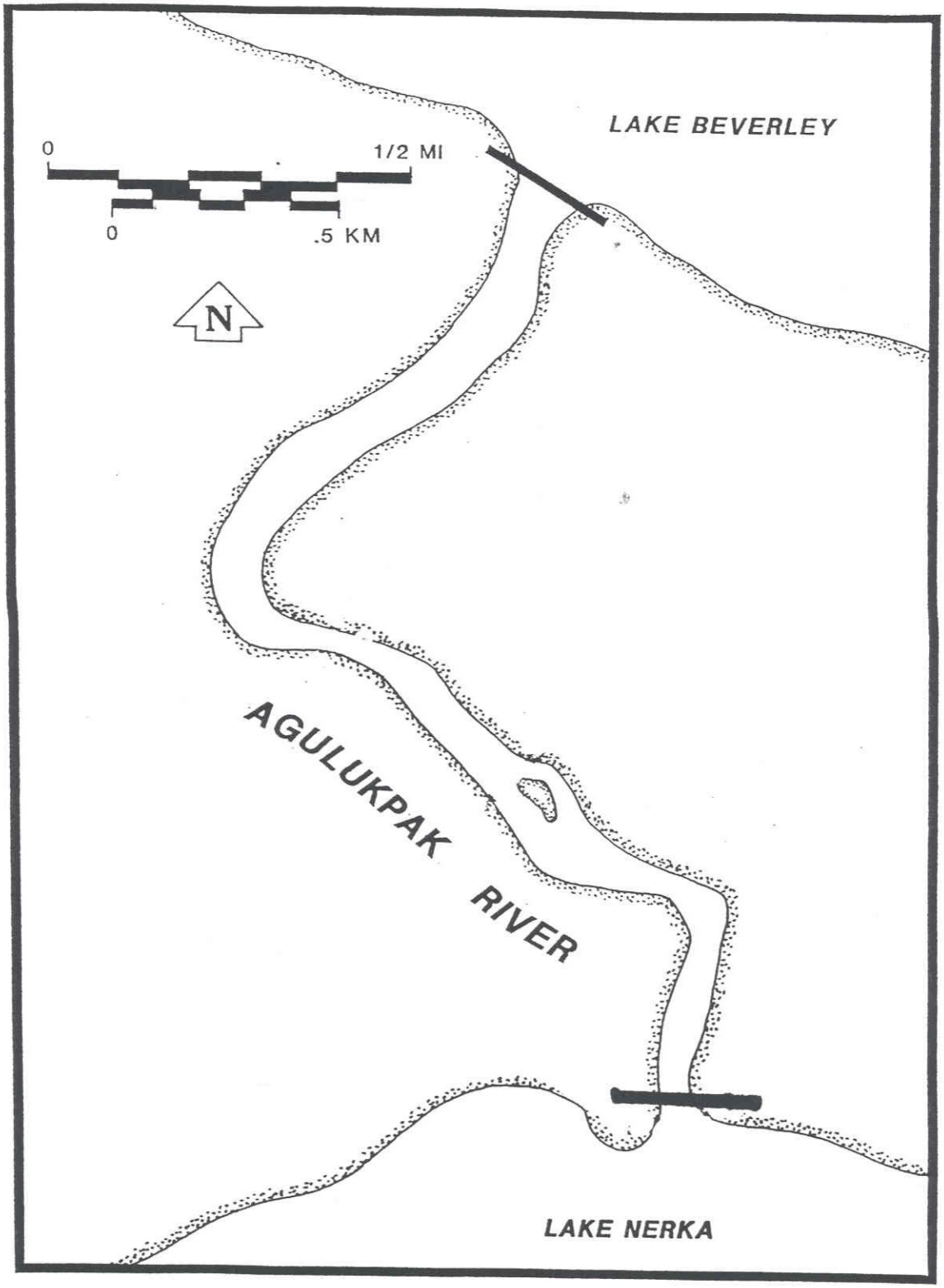

Figure 3.-Agulukpak River study site.

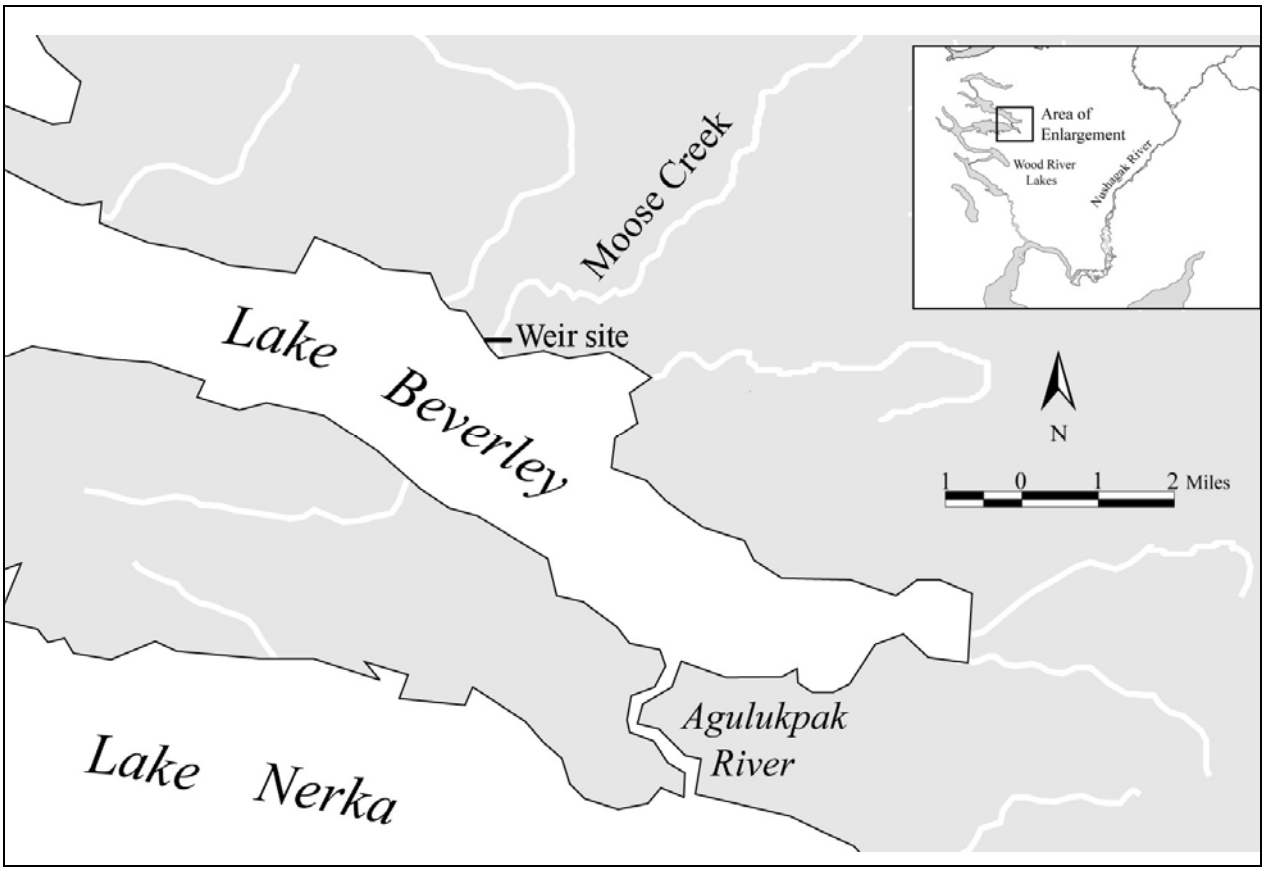

Figure 4.-Moose Creek weir site.

remainder of the year. During each survey the tracking date, tag frequency, drainage, and GPS coordinates of each located transmitter were recorded on a radio tracking form. Fixed tracking stations were operated at the inlet and outlet of both study areas. When these tracking stations detected a transmitter they recorded the date, time, antenna number, transmitter frequency, pulse code, and signal strength of the unit that passed by the station. Tracking station data were downloaded to a laptop computer whenever aerial and/or boat surveys were conducted.

Following each aerial/boat survey and fixed station download, all data pertaining to located transmitters were entered in the same MS Excel spreadsheet used to store tagging information, and all movements were recorded on hard copies of U.S. Geological Service (USGS) topographic maps. Incidental recaptures of PIT-tagged fish by division staff will also be plotted on hard copies of USGS maps.

A Monte Carlo simulation was performed to estimate the number of radio tags needed to fulfill Objective 1 in Phase 1 of the project. Simulated scenarios involved different numbers of total tags deployed and different allocations to the Agulukpak and Agulowak rivers. For each scenario, the Monte Carlo procedure determined which of a list of potential spawning tributaries had a 95% chance of receiving at least one tag. The proportion of the total spawning population

Figure 5.-Moose Creek weir, June 2005.

represented by these tributaries was then calculated. Details of the simulation can be found in Dye and Evans (*Unpublished*)[3].

If 120 radio transmitters are available (quantity allowed for according to current budget) and there is 20% tag loss (tag malfunction, physical loss of tag, or mortality of fish) and 50% are applied in the Agulowak River (50% are applied in the Agulukpak River), the simulation shows that we can be 95% certain that at least one radio transmitter will be detected in 12 tributaries representing 72% of the total spawning population.

Biological Composition

All captured rainbow trout ≥300 mm FL were measured to the nearest millimeter FL. Estimates of length composition that meet the desired objective criteria required sampling a minimum of 127 rainbow trout ≥300mm FL (Thompson 1987). The corresponding date, location, tag number, and length were recorded for each fish in the technicians' logbooks.

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[3] Dye, J. E. and D. G. Evans. *Unpublished*. Stock assessment of rainbow trout in the Wood River lakes system. Alaska Department of Fish and Game, Division of Sport Fish, FY04 Operational Plan, Anchorage.

At the end of each day the data recorded in logbooks were transferred to mark-sense AWL Form Version 1.2. After transferring the data, the technicians reviewed the completed forms and corrected obvious coding errors.

The project leader examined the mark-sense forms for obvious coding errors, clean marking, and correct header information at the end of each sampling day. The project leader prepared the forms for shipment to Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services (RTS) in Anchorage for optical scanning at the end of the field season.

Genetics

A left pectoral finclip was collected from all rainbow trout ≥300 mm FL that were captured in the Agulowak and Agulukpak rivers in August and September of 2003. Finclips were preserved in numbered vials of ethanol, and recorded in the technicians' logbook according to the date the sample was collected, length of the fish, and river the fish was captured in. Samples were organized by location and date and sent to the ADF&G genetics laboratory in the Anchorage regional office for storage until analysis of DNA markers can be completed.

The level of heterozygosity in each of the samples from the Agulowak and Agulukpak populations will be examined to determine whether the Wahlund effect (Hartl and Clark 1997) exists. Presence of the Wahlund effect, indicated by observed heterozygosities that are smaller than those predicted by Hardy-Weinberg laws, would indicate the presence of population structure among spawning groups, and justification for future collection of finclip samples from spawning aggregations. DNA markers (e.g. microsatellites, single nucleotide polymorphisms) will be used to assay the level of heterozygosity.

Anesthetic Comparison

Alternatives to clove oil as an anesthetic for fish that may be consumed later are of interest in light of recent U.S. Food and Drug Administration concerns over the health effects of eugenol (a component of clove oil). One such alternative is spearmint oil. Recent short-term experiments in a hatchery setting showed spearmint oil to maintain rainbow trout in stage 4 anesthesia for periods required sufficient for surgical radio tag insertion (Sam Ivey, Sport Fish Biologist, ADF&G, Palmer; personal communication). However, data on longer-term effects of the use of spearmint oil on rainbow trout are sparse. This study was designed to compare the survival of rainbow trout anesthetized with clove oil and spearmint oil by monitoring the survival of radio-tagged fish. However, after the first 2 weeks of use, spearmint oil was found to be an unsatisfactory means of anesthetizing Wood River rainbow trout. Thereafter, use of spearmint oil as an anesthetic was discontinued and no further long-term comparisons were made.

PHASE 2

Weir Counts

A 18 m wide, bidirectional picket weir was operated on Moose Creek approximately 300 meters upstream from its outlet to Beverley Lake (Figures 4 and 5) from May 23 through June 17, 2005.

The 5 ft tall weir pickets were made from ½ in diameter metal conduit with 3/16 in diameter holes drilled through 12 in from each end. The pickets were strung on two, 1/8 in diameter aircraft cables with ¾ in spacers made from ½ in diameter polyvinyl chloride (PVC) pipe between each picket. Pickets were assembled in 10 ft long panels that could be rolled up for transport. The panels were supported by 3/8 in diameter cable, strung across the channel on an

angle and anchored to trees on both banks. The panels were attached with cam straps and leaned against the upstream side of the cable. The flow of the creek held the panels against the bottom substrate and effectively blocked fish passage in Moose Creek. Sand bags and plastic mesh were used to fill holes and secure areas that showed signs of scouring. Metal fence posts were driven into the stream bed at a downstream angle below the weir and attached to the cable using t-shaped steel extensions to increase the rigidity of the weir. Two 16 in square openings, one for upstream and one for downstream trap placement, were located between the large panels. A pyramid-shaped trap opening and lead, located 12 in above the streambed, funneled migrating fish into the square holding pens. These pens, constructed of conduit panels, were supported by fence posts driven into the substrate. The weir traps were open to fish entry at all times except during sampling when a mesh panel sealed the traps to prevent fish from escaping.

Following weir installation, all immigrating and emigrating rainbow trout were captured, counted, measured for FL, examined for external marks, and checked for PIT tags. Fish ≥250 mm FL that were not tagged were marked with an individually numbered, green Floy T-Anchor tag placed on the left side near the posterior base of the dorsal fin, and received a pectoral finclip as a secondary mark to evaluate tag loss. Tagging was necessary so that fish passing multiple times through the weir could be discounted from the overall count. Fish <250 mm FL are not considered mature and these fish were not tagged to reduce handling mortality.

Rainbow trout telemetry data from 2003 and 2004 indicated that fish began staging in Beverley Lake near Moose Creek in April, then began ascending the creek in May, and emigrated out of Moose Creek by mid-June (J. E. Dye, 2005 memorandum to J.J. Hasbrouck, ADF&G, on summary of Wood River lakes long-term rainbow trout project, 2003-2004). This timing may vary by 1 to 2 weeks due to weather and ice conditions.

This project was designed to encompass the entire time period (April 15 through June 10) that spawning rainbow trout were immigrating to or emigrating from Moose Creek. All rainbow trout (≥250 mm FL) passing through the weir were captured and counted; therefore, the weir counts constitute a census of the spawning population of rainbow trout in Moose Creek.

All other fish species immigrating and emigrating through the Moose Creek weir were also counted.

Biological and Sexual Maturity Composition

All rainbow trout were measured for FL and visually inspected to determine sexual maturity. Collection of these data would allow for analysis of the length distribution and sexual maturity composition of the spawning population in Moose Creek in 2005.

All other fish species captured at the weir were also measured for length.

Spawning Location Surveys and Proportion of Unmarked Rainbow Trout Upstream of the Weir

At least 3 days each week, the field crew walked Moose Creek (i.e., 200 yds downstream from the weir to approximately 2 mi upstream from the weir) to visually document spawning rainbow trout. Due to a lack of suitable overwintering habitat in Moose Creek, it had been assumed that few, if any, rainbow trout would be present upstream of the weir prior to installation (i.e. fish resident to Moose Creek). During the spawning surveys rainbow trout were captured using hook

and line and examined for external marks to determine if there was a significant number of rainbow trout upstream of the weir prior to installation. Unmarked rainbow trout were tagged thereafter. Weather and water conditions determined which days each week to conduct the surveys; the ideal weather condition being a partly cloudy day with no wind ripple on the water. A GPS was used to record the coordinates of spawning and captured fish and a tally counter was used to record the number of fish observed at each location. The crew wore polarized glasses to assist in observing rainbow trout in the creek.

Water Temperature Data

Water temperatures were measured hourly at the Moose Creek weir by only a single-temperature logger; data were downloaded on a weekly basis.

DATA ANALYSIS

PHASE 1

Detection of Spawning, Feeding, and Overwintering Areas

Movement of mature rainbow trout fitted with transmitters from the Agulowak and Agulukpak rivers into and out of spawning, feeding, and overwintering areas was entered in an MS Excel spreadsheet and drawn on hard copies of USGS maps. The maps will be used to illustrate the migration patterns of rainbow trout from feeding areas to overwintering and spawning areas. Information for each fish in the MS Excel spreadsheet included: transmitter frequency, GPS coordinates, survey dates, fish transit time to area, distance to each area, rate fish travel to area, fish residence time in area, and times from tagging to detection of a mortality signal (if applicable).

Additional data recorded were numbers of radio-tagged fish to each area/stream, movements of recaptured rainbow trout from PIT tag information, and habitat characteristics and size of the areas used by tagged trout. The proportion of "applied" radio tags in each area/stream was also calculated.

Biological Composition

Mean length of rainbow trout $\geq$300 mm FL and variance was estimated in Agulowak and Agulukpak rivers using standard sample summary statistics (Cochran 1977).

The proportion of rainbow trout $\geq$300 mm FL in length class i (p_i), was estimated as follows:

$$\hat{p}_i = \frac{x_i}{x}, \tag{1}$$

where:

x_i = number of rainbow trout (>300 mm FL) of length class i, and

x = total number of rainbow trout (>300 mm FL) sampled.

The variance of this proportion was estimated by:

$$V\hat{a}r(\hat{p}_i) = \frac{\hat{p}_i(1-\hat{p}_i)}{x-1}. \tag{2}$$

A Kolmogorov-Smirnov (KS) test was used to test the null hypotheses that the length distributions of rainbow trout populations did not change over time. This was done by dividing the data into two groups: the first 50% of rainbow trout sampled from each river was one group and the second 50% sampled from each river was the second group. If no significant difference was detected then the overall sample was used to provide estimates of the length distribution of the feeding aggregation. If the length distributions of the two groups differ, then the data may not provide unbiased estimates of the length distribution of the feeding aggregations. KS tests were also used to compare length distributions between the Agulukpak and Agulowak rivers in 2003 and among length distributions over years within rivers.

Genetic Analysis

Presence of the Wahlund effect in the Agulowak River population will be assessed by comparing the observed level of heterozygosity in the sample from the Agulowak River to the level expected from Hardy Weinberg equilibrium (calculated from overall allele frequencies; Hartl and Clark 1997). Similar calculations will be made for the Agulukpak River.

Anesthetic Comparison

No statistical comparisons were made between clove and spearmint oil.

PHASE 2

Weir Counts

Daily and cumulative numbers of immigrant and emigrant rainbow trout passing through the weir were recorded and plotted against time. The cumulative number of sexually mature rainbow trout passed upstream through the weir, minus the number of recaptured fish marked at the weir, constitutes a census of rainbow trout spawning abundance in Moose Creek in 2005.

Biological and Sexual Maturity Composition

The length frequency distribution and its mean were calculated for Moose Creek.

The proportion of rainbow trout of length class *j* was calculated by:

$$\hat{p}_j = \frac{n_j}{n}, \tag{3}$$

where:

n_j = the number of rainbow trout of length class *j*, and,

n = the total number of rainbow trout measured for length.

Length distribution plots were made to determine if the distributions changed over the migration. This was done by dividing the data into two groups: the first 50% of rainbow trout measured was one group and the second 50% measured was the second group.

A logistic regression model was used to describe the sexual maturity by length relationship:

$$\pi(maturity) = \frac{e^{\beta_o + \beta_1(length)}}{1 + e^{\beta_o + \beta_1(length)}}, \tag{4}$$

where:

Maturity was coded as a dichotomous random variable (mature or not mature). The length at which 50% of the migrating rainbow trout are sexually mature (L50) was estimated by making an inverse prediction with the logistic regression model's parameter estimates. This length will be estimated as:

$$L50 = \frac{-\hat{\beta}_o}{\hat{\beta}_1}. \tag{5}$$

Spawning Location Surveys and Proportion of Unmarked Rainbow Trout Upstream of the Weir

Locations of spawning fish were plotted on USGS topographic maps.

The numbers of marked and unmarked rainbow trout captured during the surveys were recorded and the proportion of unmarked fish was calculated by:

$$\hat{p} = \frac{n}{N}, \tag{6}$$

where:

n = the number of unmarked rainbow trout, and

N = the total number of rainbow trout captured.

Water Temperature Data

As noted above hourly water temperatures were recorded at the weir. Only a summary of water temperature data will be performed.

RESULTS

PHASE 1

Detection of Spawning, Feeding, and Overwintering Areas

Tracking the radio-tagged rainbow trout indicated that at least 47% of fish tagged in the Agulowak River remained in the upper stretches of the Agulowak River (River Bay) throughout the winter. Exceptions included 3 fish that overwintered in Lake Aleknagik, 1 fish that overwintered in Little Togiak Creek, and 1 fish that overwintered in Lake Beverley.

Fifty-three percent of rainbow trout that were radiotagged in the Agulukpak River stayed in this river throughout the winter. Exceptions included 5 fish that overwintered near Spider Creek (Lake Beverley), 3 fish that overwintered in Peace River, and 1 fish that spent portions of the winter in three different creeks (e.g., Little Togiak, Beaver (Lake Nerka), and Stovall (Lake Nerka) creeks).

Movement to spawning tributaries began prior to ice out in early March. Radio-tagged fish were located in 18 tributaries of the Wood River lakes system during the spawning season (including the Agulukpak and Agulowak rivers), 12 of which were within the survey area (Table 1). On-site sampling catches of spawners and postspawners indicated that rainbow trout were spawning in 8 of the 12 tributaries (Table 1). Major spawning tributaries within the survey area included Agulukpak and Agulowak rivers, Moose, Spider, and Hope creeks in Lake Beverley, and Lynx,

Table 1.-The number and proportion of radio transmitters located in each tributary and the number of rainbow trout (spawners/postspawners) captured at each during April and May 2004.

Tributary	Lake each tributary flows to	Number of radio transmitters located in each tributary	Proportion of total radio transmitters (n=120) located in each tributary [a]	Number of rainbow trout spawners/postspawners captured during ground-truthing surveys
Within the Aerial and/or Boat Survey Area:				
Agulukpak River	Lake Nerka	32	0.27	15
Agulowak River	Lake Aleknagik	28	0.23	7
Moose Creek	Lake Beverley	6	0.05	13
Lynx Creek	Lake Nerka	6	0.05	9
Spider Creek	Lake Beverley	6	0.05	0
Hope Creek	Lake Beverley	3	0.03	10
Pike Creek	Lake Nerka	3	0.03	6
Little Togiak Creek	Lake Nerka	3	0.03	0
Teal Creek	Lake Nerka	2	0.02	0
Kema Creek	Lake Nerka	2	0.02	0
Fenno Creek	Lake Nerka	1	0.01	4
Beaver Creek	Lake Nerka	1	0.01	0
Stovall Creek	Lake Nerka	0	0.00	2
Bear Creek	Lake Nerka	0	0.00	0
Mud Creek	Lake Nerka	0	0.00	0
	Subtotal	93	0.80	66
Outside of the Aerial and/or Boat Survey Area:				
Ice Creek	Lake Aleknagik	1	0.01	0
Sunshine Creek	Lake Aleknagik	1	0.01	0
Happy Creek	Lake Aleknagik	1	0.01	0
Peace River	Lake Beverley	1	0.01	0
Wind River	Mikchalk Lake [b]	1	0.01	0
Grant River	Lake Kulik	1	0.01	3
	Subtotal	6	0.06	3
	Total	99	0.86	69

[a] Twenty-one of the original 120 radio transmitters were not located during the spawning season, therefore the sum of the proportions do not equal 1.0.

[b] Smaller lake between Lake Kulik and Lake Beverley.

Pike, Little Togiak, Teal, Kema, Beaver, and Fenno creeks in Lake Nerka (Table 1). After spawning, many fish moved back to the Agulukpak and Agulowak rivers. By mid August, most radio-tagged fish were feeding in the Agulukpak or Agulowak River. However, a few radio-tagged fish remained in Lynx, Little Togiak, Spider, Moose, and Hope creeks. The longest movement documented for an individual fish was 60 km. This fish was tagged in Agulowak River and relocated 3 months later in Moose Creek. Another fish, tagged in Agulukpak River, moved 45 km and was relocated 8 months later in Grant River (Lake Kulik).

A total of 609 rainbow trout were captured and injected with PIT tags in Phase 1 of this study. More fish were captured, as indicated below, but not all of these fish received PIT tags due to poor condition, hooking injuries, and/or they were measured but escaped prior to implantation of the tag.

Biological Composition

Rainbow trout $\geq$300 mm FL were sampled for length; 531 and 291 rainbow trout were sampled from the Agulowak and Agulukpak rivers, respectively (Figure 6). In Agulowak River the average FL of sampled rainbow trout was 393 mm with a range of 300-620 mm (Figure 7). The average FL of rainbow trout sampled in Agulukpak River was 482 mm with a range of 302-690 mm (Figure 7).

The length distribution of the first 50% of fish sampled during 2003 was not significantly different from the second 50% of fish sampled during the sampling period in either the Agulowak River (P=0.304) or Agulukpak River (P=0.073) (Figures 8 and 9).

The length distributions of the Agulowak and Agulukpak rivers were significantly different from each other during both 1992 (P<0.001) and 2003 (P<0.001) (Figures 10 and 11). The 2003 Agulowak River length distribution had a higher frequency of larger fish than 1988 (P<0.001) and a higher frequency of smaller fish than 1992 (P<0.001) (Figure 10). The 2003 length distribution in the Agulukpak River had a higher frequency of larger fish than 1992 (P<0.001) or 1996 (P<0.001) (Figure 11).

Genetic Analysis

A total of 531 and 291 pectoral fin clips were collected from rainbow trout in the Agulowak and Agulukpak rivers for genetic analysis. All samples were preserved, labeled, logged, and shipped to the ADF&G genetics laboratory in Anchorage for analysis.

Currently the ADF&G genetics lab is unable to analyze rainbow trout finclip samples due to a lack of baseline rainbow trout genetic information. Therefore, the finclip samples from the Wood River lakes system have been placed in storage at the lab until they can be processed. The project leader also investigated the possibility of sending the samples to the U.S. Fish and Wildlife Service genetics lab for analysis; however, this was cost prohibitive.

Anesthetic Comparison

Anesthetic use was alternated between spearmint and clove oil for the first 2 weeks of the project. However, after using spearmint oil to anesthetize a total of 3 rainbow trout in the Agulowak River and 8 rainbow trout in the Agulukpak River, it became obvious that spearmint oil was not appropriate for use in this study. Very high doses of spearmint oil were required for fish to reach stage-4 anesthesia, the anesthetized fish took over 30 minutes to recover, and 2 fish

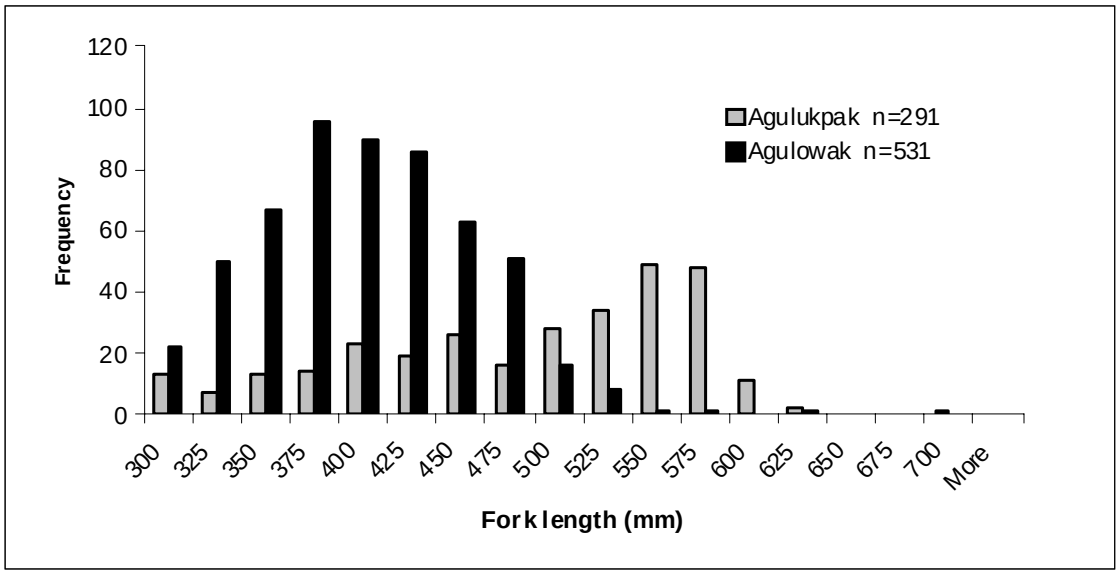

Figure 6.-Length frequency for rainbow trout sampled in the Agulowak and Agulukpak rivers during fall 2003.

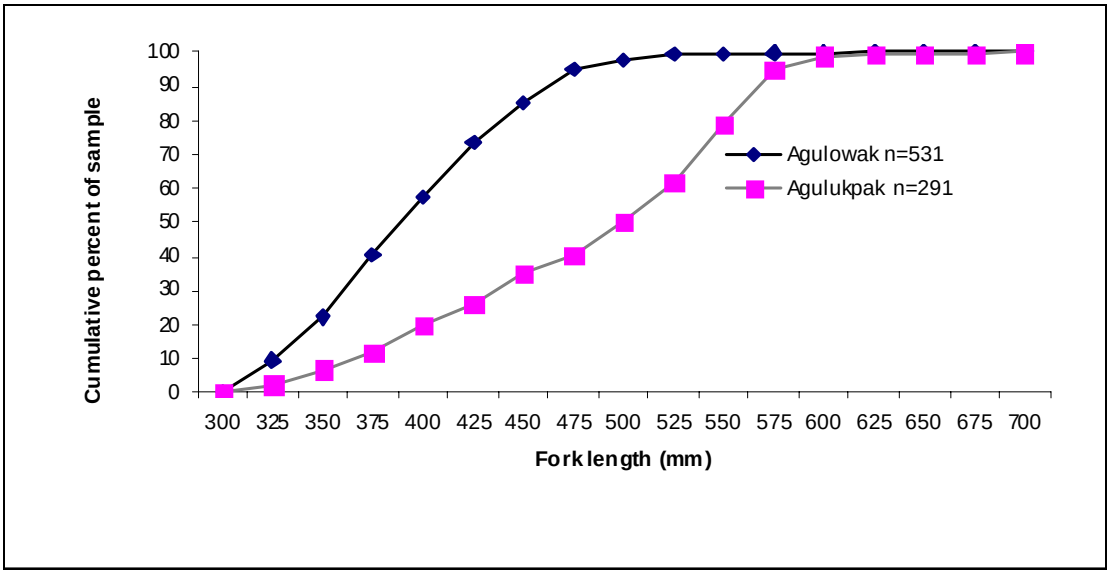

Figure 7.-Cumulative length distributions for rainbow trout sampled in the Agulowak and Agulukpak rivers during fall 2003.

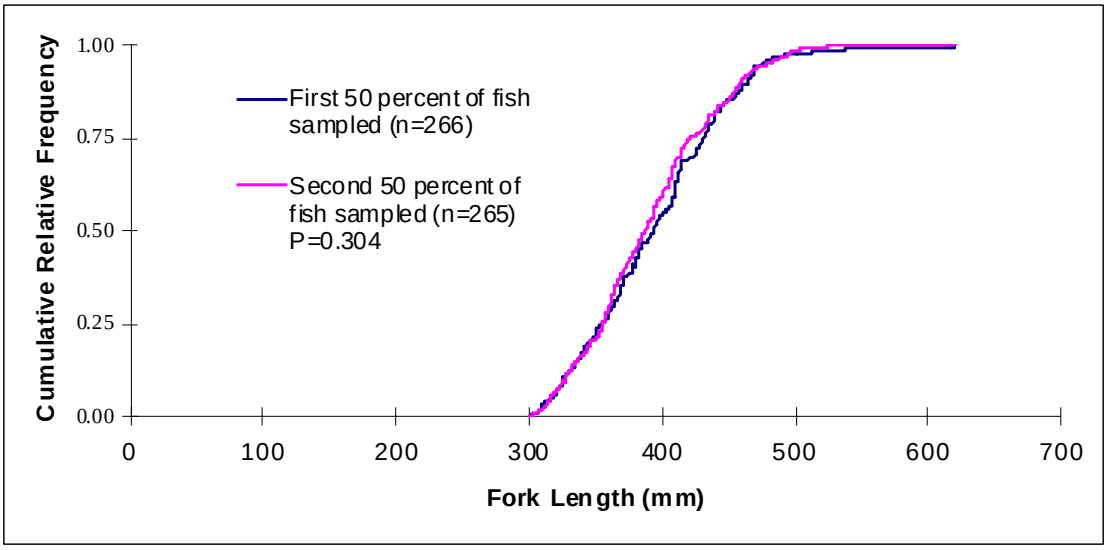

Figure 8.-Cumulative length frequency for the first and second 50 percent of rainbow trout sampled in the Agulowak River during fall 2003.

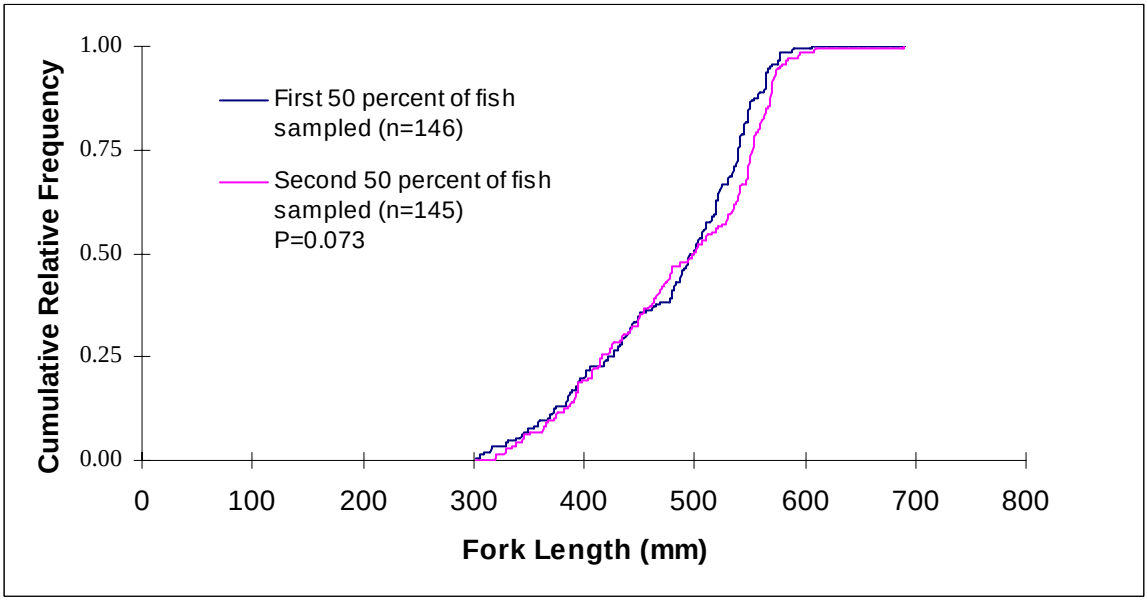

Figure 9.-Cumulative length frequency for the first and second 50 percent of rainbow trout sampled in the Agulukpak River during fall 2003.

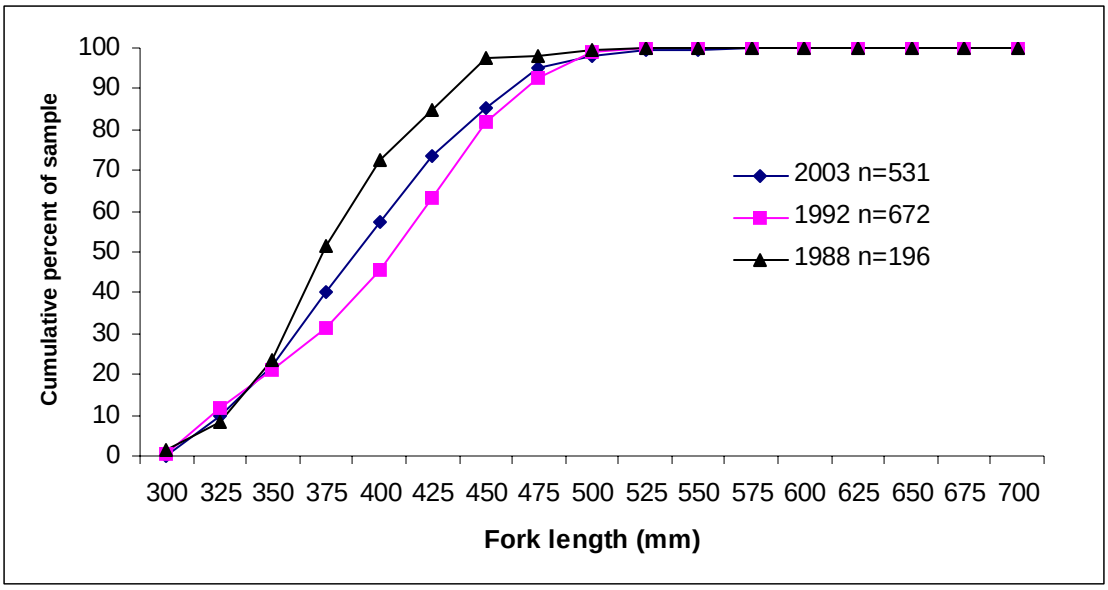

Figure 10.-Cumulative length distributions for rainbow trout sampled in the Agulowak River during fall 1988, 1992, and 2003.

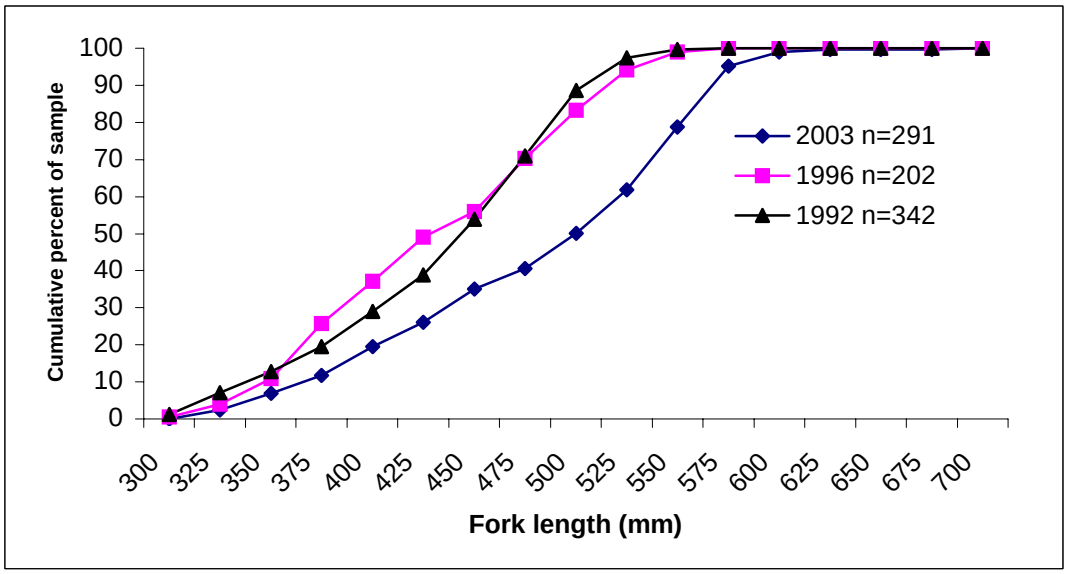

Figure 11.-Cumulative length distributions for rainbow trout sampled in the Agulukpak River during fall 1992, 1996, and 2003.

died. Therefore, after September 2, 2003, spearmint oil was no longer used to anesthetize rainbow trout and no further comparison was made between clove oil and spearmint oil.

PHASE 2

Weir Counts

The weir was installed on May 22, 2005, after multiple delays due to ice and high water conditions. A total of 145 rainbow trout ≥250 mm FL were captured and tagged at Moose Creek weir between May 23 and June 17, 2005 (Figure 12). Upstream captures of rainbow trout totaled 14 and downstream captures totaled 131. Of the 14 fish tagged in the upstream weir trap, 4 were recaptured later in the downstream box. An unknown number of rainbow trout remained above the weir and were not counted when the weir was removed. Also captured at the weir were 1,409 Arctic grayling with an average FL of 357 mm, 36 northern pike with an average FL of 545 mm, 23 round whitefish with an average FL of 343 mm, and 14 Arctic char with an average FL of 530 mm (Appendix A1).

Biological and Sexual Maturity Composition

A total of 202 rainbow trout in Moose Creek were sampled for FL during May and June 2005 (Figure 13). The average FL of these fish was 469 mm with a range of 150-660 mm.

The length distribution of the first 50% of fish sampled during 2005 had a higher frequency of smaller fish and was significantly different than the second 50% of fish sampled ($P<0.001$) (Figure 14). The logistic regression model indicated that on average a 376 mm FL Moose Creek rainbow trout will be sexually mature 50% of the time. A Hosmer-Lemeshow goodness of fit test verified that the logistic regression model fit the maturity data adequately ($P=0.19$) (Hosmer and Lemeshow 2000).

Spawning Location Surveys and Proportion of Unmarked Rainbow Trout Upstream of the Weir

Despite extensive sampling no spawning locations were visually documented due to the turbidity of the water. Sixty-one rainbow trout were captured by hook and line sampling above the weir, 41 were tagged. Fourteen of these rainbow trout were recaptured in the downstream weir trap. The proportion of marked to unmarked rainbow trout captured with hook and line was 0.163. One upstream immigrant tagged at the weir was recaptured during hook and line sampling above the weir.

Water Temperature Data

Water temperatures at the weir ranged from 7.8°C on May 22, 28, 29, 30, and 31 to 18.7°C on June 16 with a mean temperature of 11.1°C. During the estimated peak of spawning activity, May 27 through June 7, temperatures at the weir ranged from 7.8°C on May 28, 29, 30, and 31 to 15.2°C on June 5 and 6 with a mean temperature of 10.1°C.

Biological data files have been archived at Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services (Appendix B1).

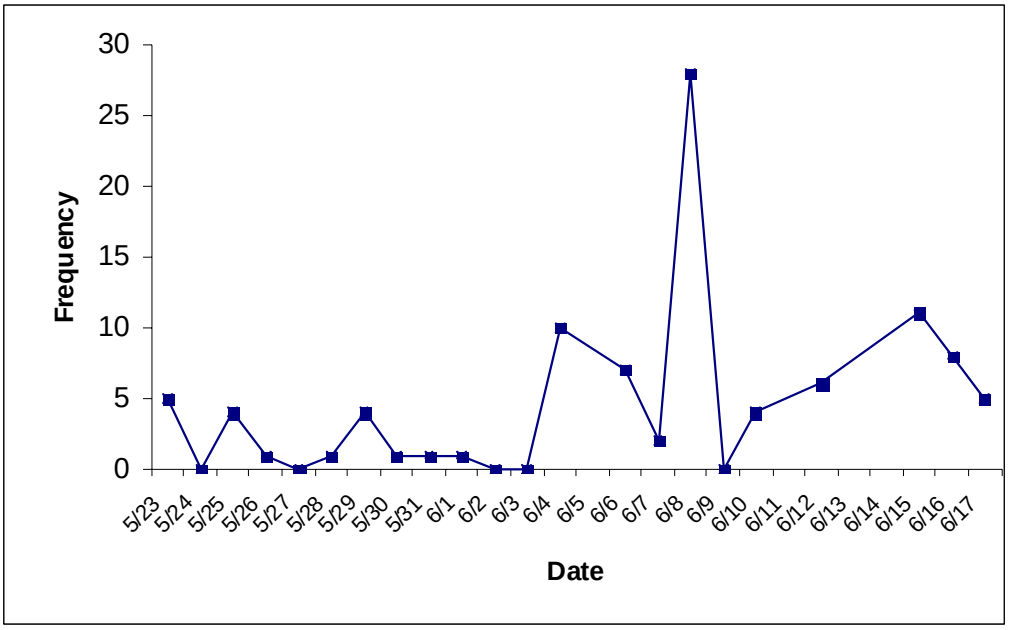

Figure 12.-Downstream passage of rainbow trout at the Moose Creek weir 2005.

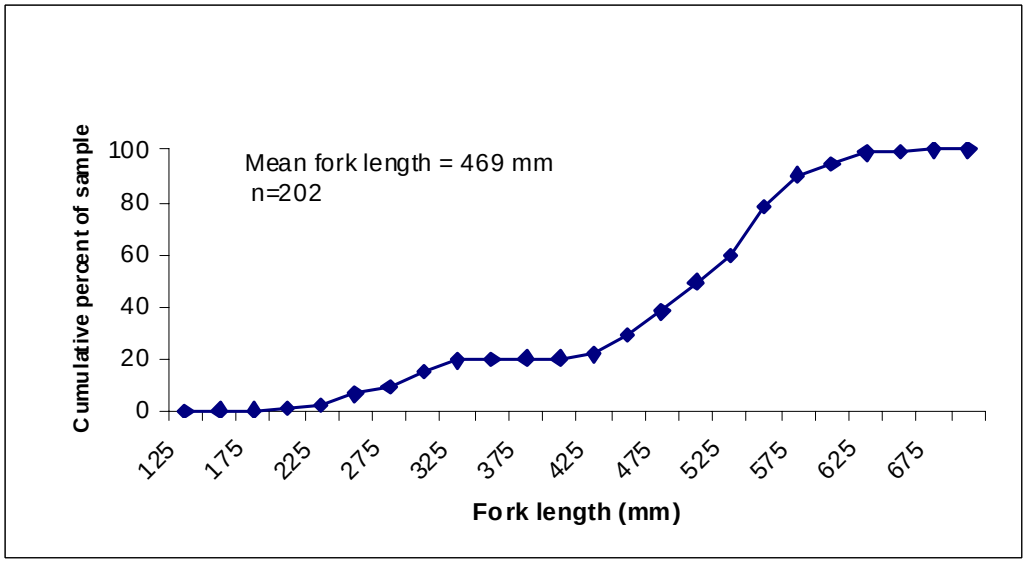

Figure 13.-Cumulative length distribution for rainbow trout sampled in Moose Creek during spring 2005.

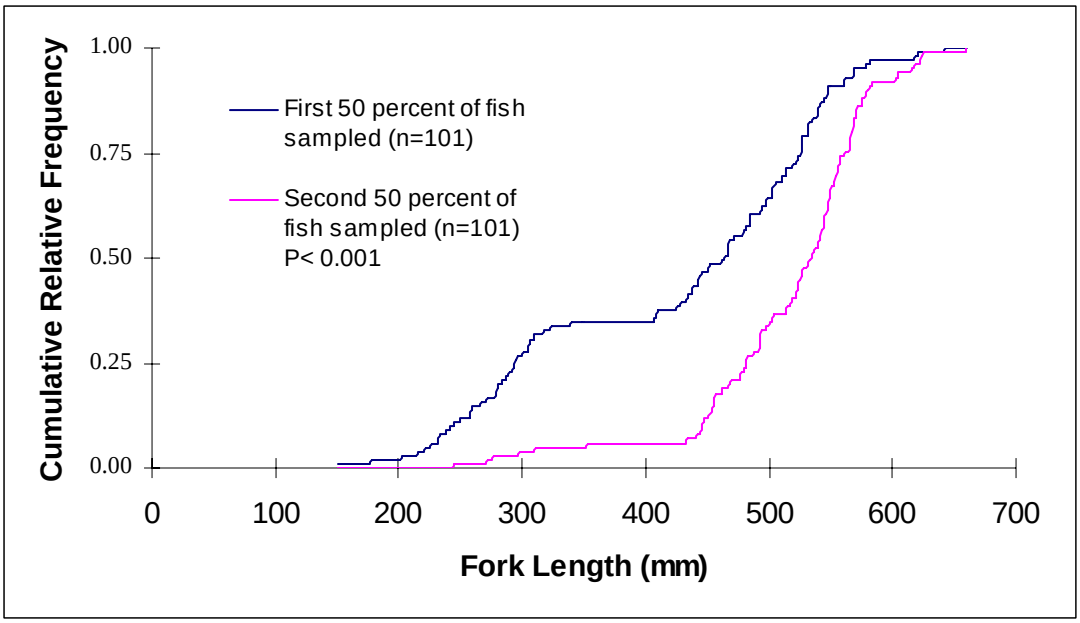

Figure 14.-Cumulative length frequency for the first and second 50 percent of rainbow trout sampled in Moose Creek during spring 2005.

DISCUSSION

PHASE 1

Tracking of radio-tagged rainbow trout indicated that the Agulowak and Agulukpak rivers support the largest spawning populations of rainbow trout in the survey area, accounting for 50% of the total radio transmitters during the spawning season (April through late May). However, 16 other tributaries were used by rainbow trout during this period (Table 1), indicating that the feeding populations at Agulowak and Agulukpak rivers during August and September comprise a number of distinct spawning populations. The tributaries containing the second largest proportions of radio-tagged rainbow trout during the spawning season were Moose, Spider, and Lynx creeks, with 6 transmitters each (5%) (Table 1). On-site sampling in Moose and Lynx creeks documented the presence of suitable spawning habitat and spawning rainbow trout (Table 1). No rainbow trout were captured in Spider Creek during sampling probably because most of the spawning habitat in Spider Creek is in its inaccessible upper reaches. Also noteworthy is that with the exception of 2 fish, no mixing occurred between the rainbow trout tagged in the Agulowak River and those tagged in the Agulukpak River. Therefore, population-specific information collected during phase-2 will be considered representative of either the Agulowak or Agulukpak River feeding populations (not both) depending on which tributary is selected for long-term study. Based on the information presented above, as well as logistical considerations, Moose Creek was chosen as the preferred weir site for phase-2 of this long-term rainbow trout investigation.

The length distribution of rainbow trout sampled during 2003 did not change during the sampling period in either the Agulowak or Agulukpak River. A comparison between the Agulowak's and Agulukpak's cumulative length distributions indicates that the Agulukpak has a much higher frequency of "trophy" rainbow trout (over 550 mm) (Figures 6 and 7). This corresponds with

previous estimated length distributions for the Agulowak and Agulukpak rivers (Dunaway 1993). In addition, the Agulukpak's length frequency distribution appears to have shifted to larger fish since the last time rainbow trout were sampled for length in 1996 (Rogan and Jaenicke 1997) (Figure 11). This increase in size could be attributed to fly-fishing only, catch and release regulations in effect since 1990 as well as large escapements of sockeye salmon contributing to the food source for rainbow trout in recent years. Length compositions of Agulowak River rainbow trout appear to have shifted to a higher frequency of slightly smaller fish since the last time fish were sampled for length in 1992 (Dunaway 1993) (Figure 10). However, the 2003 length composition indicates a higher frequency of larger fish than those sampled in 1988 (Figure 10). Recent length compositions in both the Agulowak and Agulukpak rivers appear to be near or above historical levels. However, due to some fluctuation in length compositions, periodic monitoring of rainbow trout length composition in the Agulowak and Agulukpak rivers should continue to ensure they remain healthy and productive populations.

PHASE 2

Installation of the Moose Creek weir was scheduled for April 15, 2005; however, ice and unusually high water delayed installation until May 22, 2005. The weir was in operation through June 17, 2005. Only 14 rainbow trout were passed upstream through the weir indicating that much of the immigration into Moose Creek occurred prior to weir installation. Only 4 of the 14 fish passed upstream through the weir were recaptured in the downstream trap. Additionally, only 14 of the 41 captured with hook and line upstream of the weir were recaptured in the downstream trap. This indicates that a significant number of rainbow trout remained upstream of the weir after its removal. The weir was operated later than the scheduled removal date because rainbow trout were visually observed upstream of the weir. However, due to budget and personnel constraints, the weir had to be removed before all rainbow trout had passed downstream through the weir. Therefore a complete census of the spawning population was not realized. A total of 145 mature rainbow trout were captured at the weir, as a result it can be concluded from the weir counts that the abundance of spawning rainbow trout in Moose Creek exceeded 145 fish during 2005. Due to the fact that much of the rainbow trout immigration into Moose Creek was missed, the marked to unmarked ratio of rainbow trout captured with hook and line upstream of the weir was very low and did not indicate if rainbow trout overwinter in Moose Creek. In 2006 the weir will be installed immediately following ice out and, if possible, remain in operation until all rainbow trout have emigrated from Moose Creek. This will allow for a census of the spawning population. Additionally, if we are unable to enumerate all mature rainbow trout at the weir in 2006, we will estimate abundance using mark-recapture techniques.

The length distribution of rainbow trout sampled in Moose Creek during 2005 changed from the first 50% of fish sampled to the second 50% of fish sampled. The length distribution shifted toward larger fish later in the year. This can likely be attributed to the fact that much of the immigration of larger, mature spawners was missed at the weir and not detected until they began passing downstream through the weir following spawning. On average, a 376 mm FL Moose Creek rainbow trout will be sexually mature 50% of the time.

ACKNOWLEDGMENTS

We would like to thank Troy Jaecks, Ethan Ford, Anthony Rajek, Matthew Albert, and Paul Lester for their dedication and hard work on the field portion of this project. We would also like to thank David Evans for his biometric design and review of this project.

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APPENDIX A. DAILY PASSAGE OF OTHER RESIDENT FISH SPECIES AT MOOSE CREEK WEIR, SPRING 2005

Appendix A1.-Daily passage of Arctic grayling, Arctic char, round whitefish, and northern pike at the Moose Creek weir during spring 2005.

	Number of Fish			
Date	Arctic grayling	Arctic char	Round whitefish	Northern pike
5/22	0	0	0	0
5/23	4	0	0	3
5/24	2	0	1	1
5/25	18	0	7	3
5/26	35	0	1	2
5/27	25	0	0	1
5/28	4	0	0	0
5/29	16	0	0	1
5/30	0	1	0	1
5/31	12	1	5	1
6/01	38	2	0	0
6/02	41	2	0	0
6/03	79	2	0	0
6/04	345	3	2	2
6/05	295	0	0	0
6/06	224	0	0	1
6/07	40	0	4	2
6/08	44	0	1	3
6/09	28	0	0	2
6/10	48	0	1	3
6/11	57	2	1	0
6/12	10	0	0	0
6/13	1	0	0	0
6/14	0	0	0	0
6/15	31	0	0	2
6/16	0	0	0	0
6/17	12	1	0	8
Total	1,409	14	23	36

APPENDIX B. LIST OF ARCHIVED BIOLOGICAL DATA FILES

Appendix B1.-List of biological data files for resident fish species captured and sampled in the Wood River lakes system, 2003 and 2005.

File Name	Description (location, species, captured technique, data collected, dates sampled)
t-000401b012003.dta	Agulowak R; Arctic grayling; hook & line; length data, 27-31 May 2003
t-000401b022003.dta	Agulowak R; Dolly Varden/Arctic char; hook & line; length data, 27 Aug-22 Sept 2003
t-000401b032003.dta	Agulowak R; rainbow trout; hook & line; length, sex, & tag data, 26 Aug-24 Sept 2003
t-000402b012003.dta	Agulukpak R; rainbow trout; hook & line; length, sex, & tag data, 12 Aug-25 Sept 2003
t-000402b022003.dta	Agulukpak R; Arctic grayling; hook & line; length data, 14 Aug-16 Sept 2003
t-000402b032003.dta	Agulukpak R; Arctic grayling; gill net; length data, 1-15 Sept 2003
t-000402b042003.dta	Agulukpak R; rainbow trout; gill net; length, sex, & tag data, 31 Aug-16 Sept 2003
t-000402b052003.dta	Agulukpak R; Dolly Varden/Arctic char; hook & line; length data, 31 Aug-18 Sept 2003
t-000402b062003.dta	Agulukpak R; Dolly Varden/Arctic char; gill net; length data, 31 Aug-16 Sept 2003
t-000400b012005.dta	Moose Ck; whitefish; weir; length data, 24 May-11 Jun 2005
t-000400b022005.dta	Moose Ck; Dolly Varden/Arctic char; weir; length data, 30 May-11 Jun 2005
t-000400b032005.dta	Moose Ck; northern pike; weir; length data, 23 May-10 Jun 2005
t-000400b042005.dta	Moose Ck; Arctic grayling; weir; length data, 24 May-13 Jun 2005
t-000400b052005.dta	Moose Ck; rainbow trout; hook & line; length, sex, & tag data, 12 May-10 Jun 2005
t-000400b062005.dta	Moose Ck; rainbow trout; weir; length, sex, & tag data, 23 May-16 Jun 2005

Note: Text files of data scanned from mark-sense forms (ADF&G, Standard Age Weight Length, Form Version 1.2). Archived at the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage, AK 99518-1565.