Fishery Data Series No. 05-01

Study of Dolly Varden in Cooper Creek, Kenai Peninsula, Alaska, 1999-2001

Final Report for Study 00-038
USFWS Office of Subsistence Management
Fishery Information Services Division

by

Jeffery A. Breakfield,

L. Saree Timmons,

and

Patricia A. Hansen

March 2005

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics (F, t, χ^2, etc.)	
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
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. 05-01

STUDY OF DOLLY VARDEN IN COOPER CREEK, KENAI PENINSULA, ALASKA, 1999-2001

FINAL REPORT FOR STUDY 00-038
USFWS OFFICE OF SUBSISTENCE MANAGEMENT
FISHERY INFORMATION SERVICES DIVISION

by
Jeffery A. Breakfield,
Division of Sport Fish, Soldotna,
L. Saree Timmons,
Division of Sport Fish, Anchorage,
and
Patricia A. Hansen
Division of Sport Fish, Research and Technical Services, Anchorage

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

March 2005

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

Jeffery A. Breakfield,
Alaska Department of Fish and Game, Division of Sport Fish
43961 Kalifornsky Beach Rd, Soldotna, Alaska 99669-8367, USA

L. Saree Timmons,
Alaska Department of Fish and Game, Division of Sport Fish
333 Raspberry Road, Anchorage, Alaska, 99518-1599, USA

and

Patricia A. Hansen,
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599, USA

This document should be cited as:
Breakfield, J. A., L. S. Timmons, and P. A. Hansen. 2005. Study of Dolly Varden in Cooper Creek, Kenai Peninsula, Alaska, 1999-2001. Alaska Department of Fish and Game, Fishery Data Series No. 05-01, Anchorage.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 907-465-3646, or (FAX) 907-465-2440.

TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES ii

ABSTRACT 1

INTRODUCTION 1

Objectives 5

METHODS 5

Field Sampling 5
Data Analysis 6
Abundance Estimate 6
Length Composition 7

RESULTS 7

1999 Study 7
2000 Study 9
2001 Study 12

DISCUSSION 13

ACKNOWLEDGEMENTS 14

REFERENCES CITED 14

LIST OF TABLES

Table **Page**

1. Counts of Dolly Varden moving past the Cooper Creek weir, by fate and direction of movement, 1999-2001....9
2. Number and percent of Dolly Varden moving downstream past the weir that were or were not recaptures, by year....10
3. Length composition of Dolly Varden captured at the weir at Cooper Creek, 1999-2001....10

LIST OF FIGURES

Figure **Page**

1. Kenai River drainage....2
2. Cooper Creek drainage and weir location....3
3. Harvest and catch of Dolly Varden from the Kenai River drainage, 1977-2001....4
4. Number of Dolly Varden migrating through the Cooper Creek weir, by date and direction of travel, and average weekly water temperature, 1999-2001....8
5. Length distribution of Dolly Varden captured at the Cooper Creek weir, 1999-2001....11

ABSTRACT

During the periods 27 August-6 October 1999, 15 July-20 October 2000, and 19 July-19 October 2001, a weir was operated on Cooper Creek, a tributary of the Kenai River in Alaska, to study Dolly Varden *Salvelinus malma*. Dolly Varden captured at the weir that were ≥200 mm were tagged and measured to the nearest millimeter FL. In 1999, minimum spawning abundance was 314 Dolly Varden; in 2000 minimum abundance was 192 fish; and in 2001, minimum abundance was 470. However, many fish were not counted, as evidenced by the truncated migration data. Dolly Varden were captured in the upstream trap as soon as it was installed in mid-July and downstream movement was still increasing when the weir was removed in late October. In addition, a large proportion of downstream-moving fish captured at the weir were untagged. In all 3 years, most captured Dolly Varden were 400-549 mm FL.

Key words: Cooper Creek, Kenai River, Kenai Peninsula, Dolly Varden, weir, length composition, *Salvelinus malma*.

INTRODUCTION

Cooper Creek is a tributary to the Kenai River and is located in the Chugach National Forest between Cecil Rhode and Cooper mountains (Figure 1). Cooper Creek historically drained Cooper Lake, but the lake is now dammed on the west side and releases no water into Cooper Creek. Instead, springs and snow runoff in the area below the dam form the headwaters. Stetson Creek joins Cooper Creek approximately 1 mile below the dam and provides most of the water for the creek (Figure 2). Water temperatures of Cooper Creek range from only 5-10°C because the headwaters are in subalpine terrain.

The Kenai River drainage is the most heavily utilized system for freshwater sport fishing in Alaska. Although most anglers participate in the river's Pacific salmon fisheries for Chinook *Oncorhynchus tshawytscha*, sockeye *O. nerka*, and coho *O. kisutch* salmon, the drainage also supports fisheries for other species, including a major fishery for Dolly Varden *Salvelinus malma*. Sport harvest of Dolly Varden from the Kenai River peaked at almost 35,000 fish in the late 1970s and early 1980s (Figure 3). Concern about sustainability of these harvests prompted reduced bag limits in 1986, which resulted in drastically reduced harvests. However, catch, which was not estimated until 1990, has exceeded 50,000 Dolly Varden annually since 1991, peaking at over 100,000 fish in 2000 and 2001 (Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004; Mills 1992-1994; Walker et al. 2003; Figure 3).

Although fishing for salmon is not allowed in many Kenai River tributaries such as Cooper Creek, fishing for resident species is. Because of concerns about possible overfishing, beginning in 1999, a spawning season closure was implemented in Cooper Creek, believed to be a major spawning area for Dolly Varden. This closure prevents fishing from April 15 through June 10 and September 15 through October 31.

Although concerns for Kenai River Dolly Varden have lessened due to these highly restrictive regulations, the population is relatively small and easily accessible to anglers, particularly when fish are concentrated in small tributaries during spawning. To ensure sustainability of Kenai River Dolly Varden, several studies were undertaken in the mid-1990s. The U.S. Fish and Wildlife Service (USFWS) has investigated movements of Dolly Varden upstream of Skilak Lake since 1996. The Alaska Department of Fish and Game (ADF&G), Sport Fish Division has conducted studies to locate spawning, rearing, and holding areas since 1997.

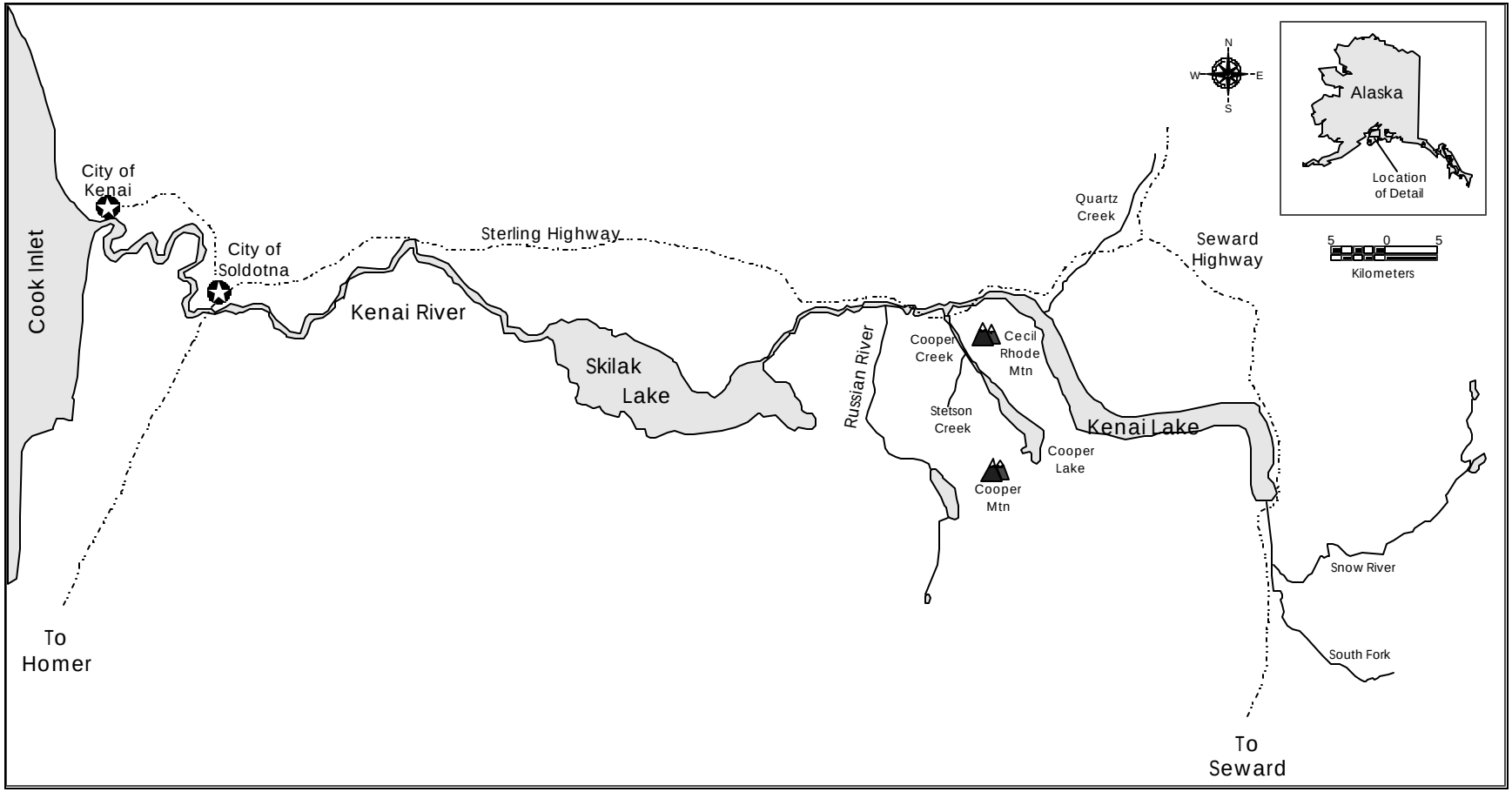


Figure 1.-Kenai River drainage.

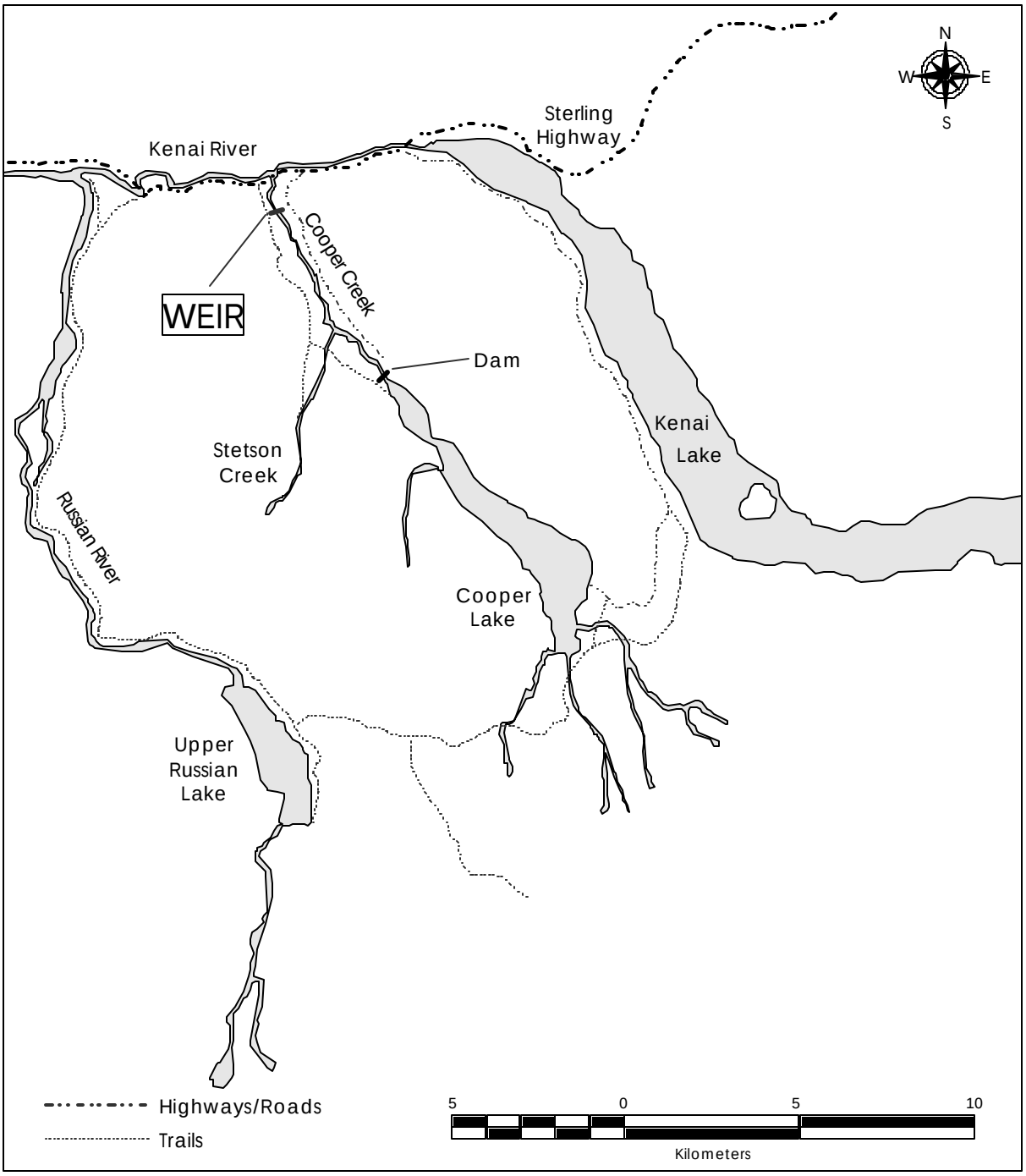
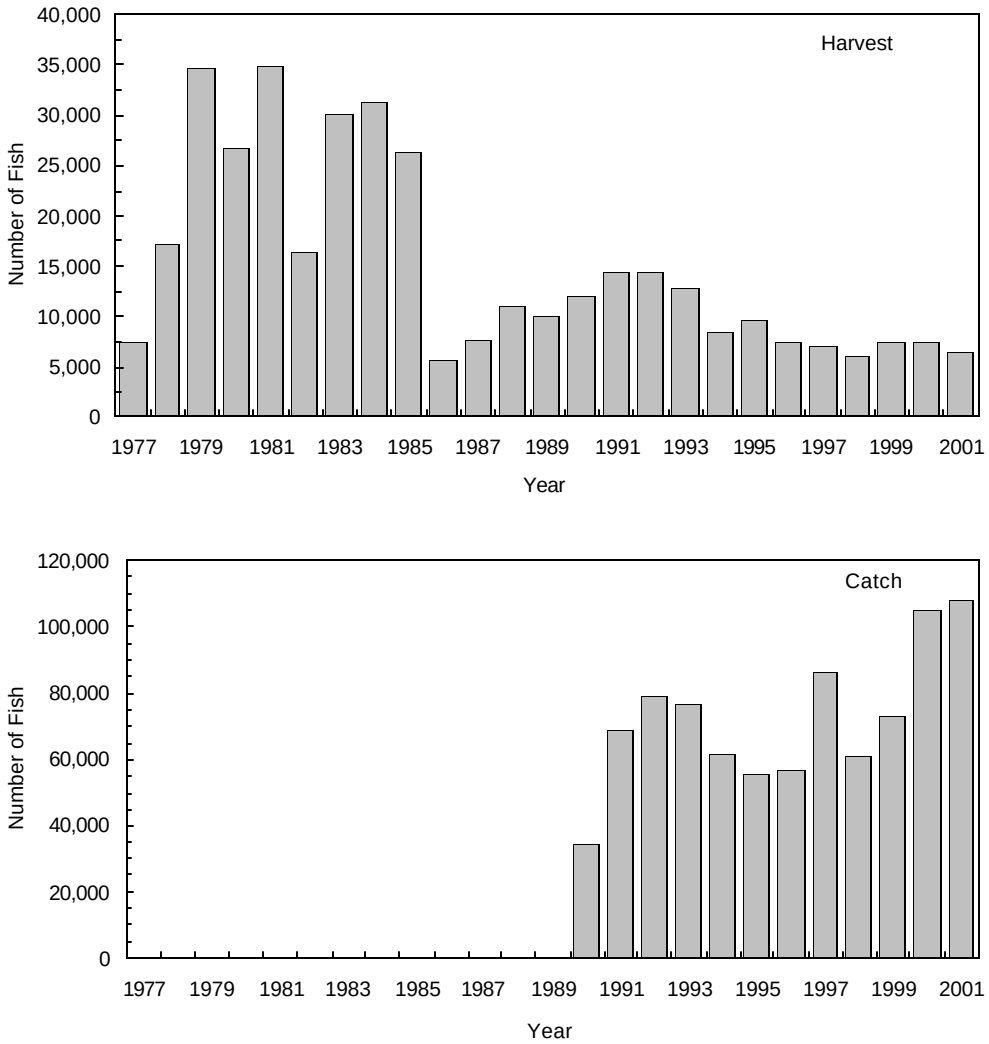


Figure 2.-Cooper Creek drainage and weir location.



Source: Statewide Harvest Survey (Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004; Mills 1979-1994; Walker et al. 2003).

Figure 3.-Harvest and catch of Dolly Varden from the Kenai River drainage, 1977-2001.

Dolly Varden is a complex species, with many populations exhibiting complicated migratory and homing patterns involving lake and non-lake watersheds (Armstrong 1965; 1984; Sonnichsen 1990). Anadromous southern form Dolly Varden (Behnke 1980), which could include those of the Kenai Peninsula, typically overwinter in lakes, but may spawn in the fall in either a lake system or a non-lake system. Cooper Creek is a non-lake system although it was connected to Cooper Lake in the past as described above.

Beginning in 1998, a three-part study was initiated to study Kenai River Dolly Varden. ADF&G and USFWS combined resources to fund radiotelemetry studies to track the movement of several spawning populations in tributaries upstream of Skilak Lake. These include Quartz Creek, South Fork of the Snow River, and Cooper Creek. This report documents results of the Cooper Creek weir project; results of the radiotelemetry and Snow River projects will be documented in subsequent reports. Information from these projects will assist fisheries managers in evaluating current regulations and will assist the Federal Subsistence Board regarding potential subsistence fisheries in the upper Kenai River.

OBJECTIVES

Objectives of this project were to:

1. Census the abundance of spawning Dolly Varden ≥200 mm FL in Cooper Creek during September 1999, 2000, and 2001; and
2. Determine the length composition of spawning Dolly Varden ≥200 mm FL in Cooper Creek during September 1999, 2000, and 2001.

METHODS

FIELD SAMPLING

A weir, consisting of floating panels, was installed in Cooper Creek near the confluence of the Kenai River (Figure 2) to census all Dolly Varden ≥200 mm FL immigrating into Cooper Creek. The weir design was similar to that of Larson (1997). The floating weir pickets were 1.9 cm diameter, schedule 40, PVC tubes spaced 1.6 cm apart. Each floating panel was 1.25 m wide x 4.5 m long. These panels were fastened to the river bottom by an anchor cable hinge system. The angle of the panels with the river bottom and the water surface varied with water depth. A subsurface resistance board provided lift to the floating panels. Traps were installed to capture both up- and downstream migrating fish. The rigid trap pickets were 1.25 cm diameter solid aluminum rods placed in an aluminum channel framework with a 1.25 cm gap between pickets. The channel frames were 3.6 m long x 1.0 m wide x 1.05 m high. A 0.5 m wide x 1.0 m long metal rebar frame covered with plastic vexar was used as a recovery pen for fish released upstream. This recovery pen had a 10 cm x 10 cm opening in the upstream end allowing fish to leave after recovery.

The weir was manned 24-hours per day and passage of all Dolly Varden was tallied each day from 27 August-6 October 1999, from 15 July-20 October 2000, and from 19 July-19 October 2001. All captured Dolly Varden were restrained in a tagging cradle (Larson 1995) and were measured from tip-of-snout to fork-of-tail (FL); lengths were recorded to the nearest millimeter.

All Dolly Varden ≥200 mm FL were marked with an individually numbered Floy™ T-Anchor tag inserted on the left side of the fish between the basal rays of the dorsal fin. Exceptions were fish with extreme morphological damage such as deep scars or lesions, damaged gill filaments, a lethargic condition, or otherwise appearing unlikely to survive. Fish were then placed into a holding pen in the creek allowing them to leave after recovery.

In 1999, we clipped the adipose fin from all tagged Dolly Varden as a secondary mark to investigate tag loss. In 2000 and 2001, we did not clip adipose fins because 1999 data indicated that Floy tags were not shed.

In all years, a complete census of Dolly Varden migrating upstream was attempted, and problems were encountered in all years. In 1999 late installation of the weir and a period when weir integrity was compromised due to high water precluded a complete census. Marking fish allowed us to attempt a capture-recapture experiment to estimate abundance, using the weir as the capture event and sampling above the weir as the recapture event.

To recapture Dolly Varden in 1999, we sampled two sections above the weir: (1) from Stetson Creek downstream approximately 2 miles on 28 and 29 September; and (2) from the weir upstream approximately 2 miles on 30 September and 4 October (Figure 2). All Dolly Varden were captured by rod-and-reel and were measured to the nearest millimeter FL, examined for presence of a tag or fin clip, untagged fish ≥200 mm FL were tagged with a Floy tag as described above, and then each fish was released.

In 2000 and 2001, Dolly Varden were captured at the weir immediately upon installation, the weir was removed before the downstream migration was finished, and was not fish tight. A mark-recapture experiment was attempted using the upstream migration as the first event and the downstream migration as the second event. All Dolly Varden migrating downstream through the weir were examined for tags and finclips and were measured. All untagged Dolly Varden ≥200 mm FL were tagged with Floy tags as described above and lengths recorded.

Water depth readings at the weir were recorded daily at 0900 hours, and temperature was recorded twice daily at 0900 and 2200 hours.

DATA ANALYSIS

Abundance Estimate

A closed population capture-recapture model was attempted to estimate abundance each year. Assumptions necessary to estimate abundance with this model are (Seber 1982):

1. The population is closed with no additions or losses among capture events (through recruitment, death, immigration, or emigration);
2. All fish have an equal capture probability during all capture events or marked fish mix completely with unmarked fish after marking;
3. Marking does not affect capture probability in subsequent capture events;
4. Marks (tags) are not lost between events; and
5. All marked fish recaptured during subsequent capture events are correctly identified and recorded.

A closed population abundance estimator can still be used if no more than one of the following occurs: recruitment, death, immigration, or emigration. Recruitment through birth or growth would not be possible during September and October. However, immigration and emigration occurred during the study. Tagging mortality was not likely to be a problem because of the short duration of the study.

To determine if assumption 2 was met we planned to test for size selectivity by comparing lengths of fish captured during the first event to fish captured during the second event. We were to use a Kolmogorov-Smirnov test (Conover 1980) to compare cumulative length distributions of fish marked

during the first event to fish recaptured during the second event, and then compare cumulative length distributions of fish marked during the first event to all fish (marked and unmarked) captured during the second event. The crew handled and marked fish carefully to minimize the possibility that marking affected the probability of subsequent capture (assumption 3). To meet assumption 4, in 1999 adipose fins were clipped as a secondary mark to assess tag loss; based on low tag loss in 1999, we did not clip adipose fins in 2000 and 2001. In all years, tag numbers were read and recorded carefully to minimize problems of marked fish not being detected (assumption 5).

After evaluating assumptions, abundance was to have been estimated. However, due to violations of assumptions in all years (see Results), a minimum estimate was calculated as the sum of fish marked at the weir, unmarked fish captured upstream of the weir (in 1999 only), and unmarked fish captured moving downstream at the weir.

Length Composition

The proportion of Dolly Varden in length class j and its variance was estimated as a binomial proportion (Cochran 1977) by:

$$\hat{p}_j = \frac{n_j}{n}, \tag{1}$$

$$\mathrm{Var}\,(\hat{p}_j) = \frac{\hat{p}_j(1-\hat{p}_j)}{n-1}, \tag{2}$$

where:

n_j = the number of Dolly Varden of length class j; and

n = the total number of Dolly Varden sampled for length.

RESULTS

1999 STUDY

In 1999, the weir was installed and operational on 27 August. Water temperature varied from 13.0°C on 2 September to 2.0°C on 3 October. Average weekly temperature decreased steadily during the study (Figure 4). The weir structure was not fish tight during its entire operation. Water levels varied considerably throughout the duration of the weir operation, were relatively high and, on occasion, created small cavities along the rail substrate and rigid weir structures. Erosion of the streambed may have allowed some fish to pass through the weir undetected.

We captured and released alive 291 Dolly Varden ≥200 mm FL moving upstream at the weir or with hook-and-line above the weir (Table 1). We captured Dolly Varden in the upstream trap as soon as the weir was installed (Figure 4). The highest concentration of upstream migrating Dolly Varden was during the week of 16-22 September (Figure 4). Fish were still moving upstream when the weir was removed on 6 October. Dolly Varden started migrating downstream the week of 23-29 September (Figure 4), but only 23 fish were captured moving downstream before the weir was removed (Table 1). Of those, 30% were not recaptures (Table 2).

The weir was not operational until 27 August, well after the start of the upstream migration, and when the weir was removed on 6 October, fish were still moving upstream and the downstream migration had

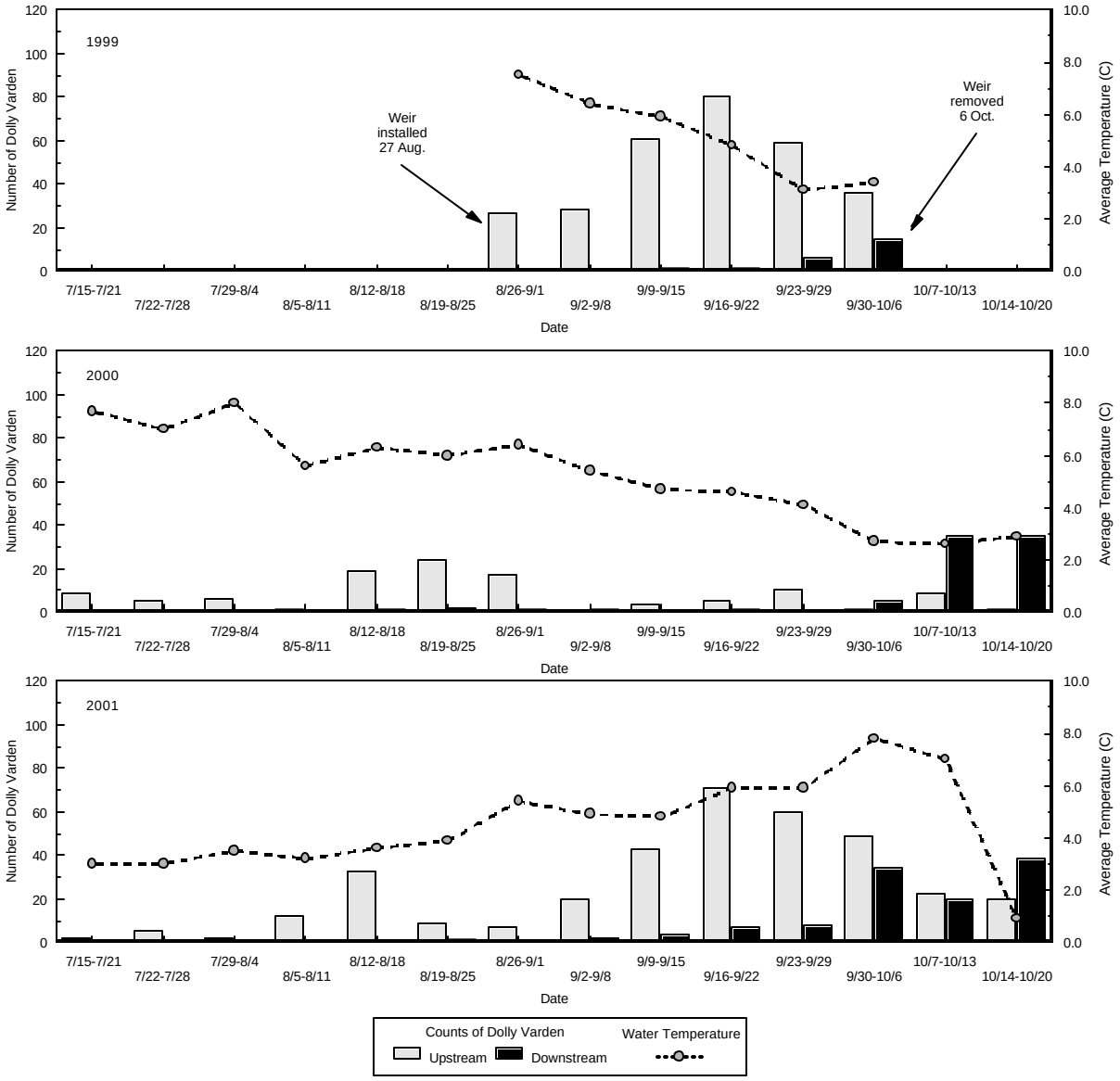


Figure 4.-Number of Dolly Varden migrating through the Cooper Creek weir, by date and direction of travel, and average weekly water temperature, 1999-2001.

begun. Thus, because there was both immigration and emigration the population could not be considered closed, violating Assumption 1 of the capture-recapture experiment, and the two-sample abundance estimate was not calculated. Therefore, minimum spawning abundance was 314 Dolly Varden ≥200 mm in 1999 (Table 1), which was the sum of fish marked at the weir, unmarked fish captured upstream of the weir, and unmarked fish captured moving downstream at the weir.

Most Dolly Varden captured in 1999 were between 400-549 mm (Table 3; Figure 5).

Table 1.-Counts of Dolly Varden moving past the Cooper Creek weir, by fate and direction of movement, 1999-2001.

Direction	Fate	Count
1999		
Up[a]	Survived	291
Down	Mortality	4
Down	Survived	19
Minimum Spawning Abundance		314
2000		
Up	Survived	111
Down	Mortality	4
Down	Survived	77
Minimum Spawning Abundance		192
2001		
Up	Survived	355
Down	Mortality	25
Down	Survived	90
Minimum Spawning Abundance		470

[a] Includes fish captured by hook-and-line above the weir.

We documented five sockeye salmon actively spawning in Cooper Creek approximately 100 feet downstream of the weir. We did not observe other salmon spawning in Cooper Creek. We passed 20 Dolly Varden <200 mm FL that were sampled but not tagged, 1 pink salmon, 4 coho salmon, and 2 rainbow trout *O. mykiss* upstream through the weir.

2000 STUDY

In 2000, the weir was installed and operational on 15 July. Temperature ranged from 3.0°C to 15.0°C. Average weekly temperature decreased steadily during the study (Figure 4). The weir structure was not considered fish tight during its entire operation. Water levels varied and were relatively high throughout the duration of the weir operation and, on occasion, created small cavities along the rail substrate and rigid weir structures. Erosion of the streambed may have allowed some fish to pass through the weir or around it undetected.

Table 2.-Number and percent of Dolly Varden moving downstream past the weir that were or were not recaptures, by year.

Recaptured	Number	Percent
1999		
No	7	30.4
Yes	16	69.6
Total	23	100.0
2000		
No	77	95.1
Yes	4	4.9
Total	81	100.0
2001		
No	104	90.4
Yes	11	9.6
Total	115	100.0

Table 3.-Length composition of Dolly Varden captured at the weir at Cooper Creek, 1999-2001.

	1999		2000		2001	
Length (mm)[a]	Number	Percent	Number	Percent	Number	Percent
200-249	3	1.0	1	0.5	18	3.9
250-299	2	0.6	3	1.6	10	2.1
300-349	7	2.2	15	7.9	10	2.1
350-399	14	4.5	16	8.4	20	4.3
400-449	79	25.2	28	14.7	95	20.3
450-499	108	34.4	74	38.7	166	35.5
500-549	75	23.9	45	23.6	108	23.1
550-599	21	6.7	8	4.2	36	7.7
600-649	5	1.6	1	0.5	4	0.9
Total	314	100	191	100	467	100

[a] In 2000, 1 fish had no length data. In 2001, 3 fish had no length data.

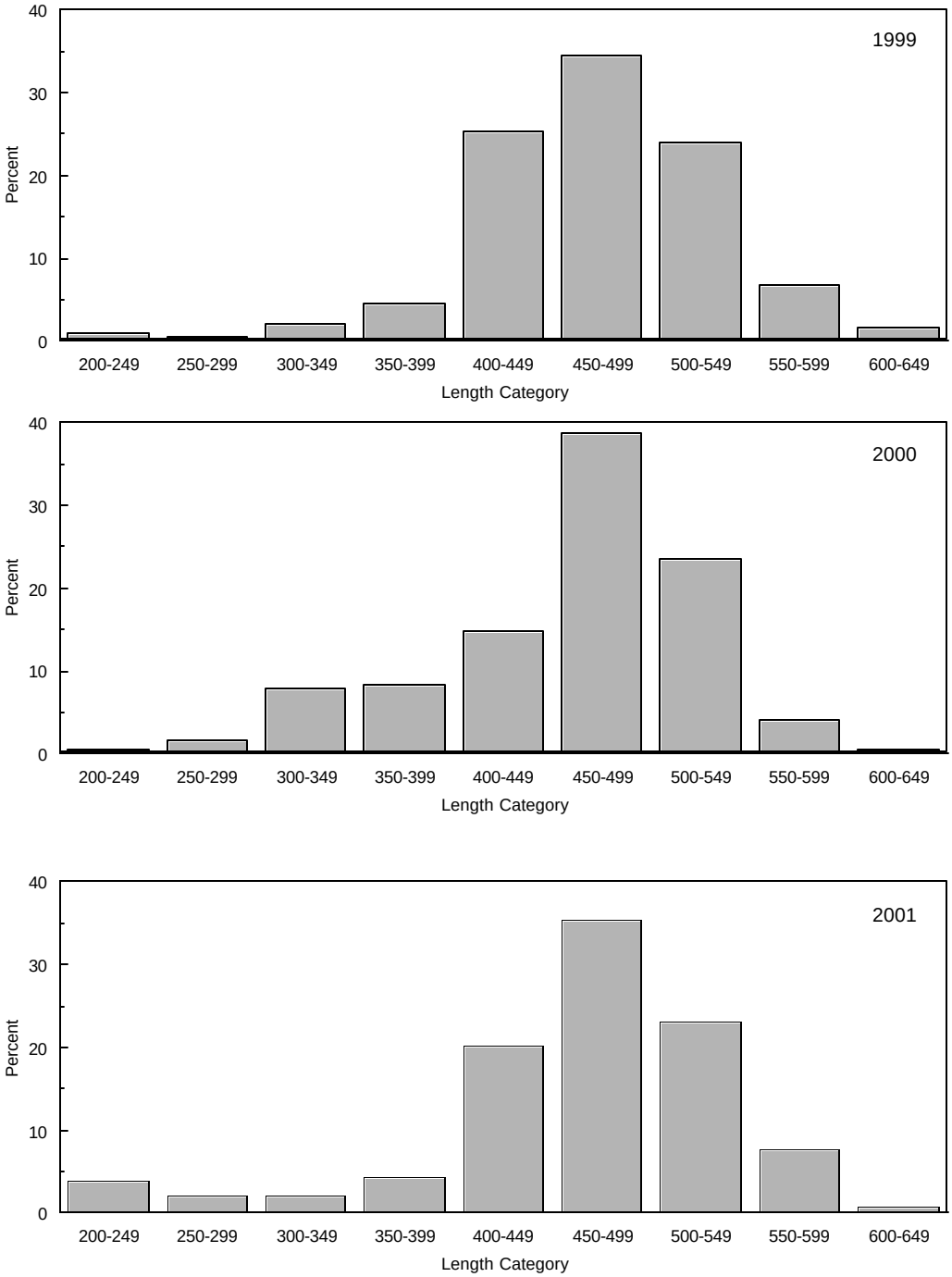


Figure 5.-Length distribution of Dolly Varden captured at the Cooper Creek weir, 1999-2001.

We captured and released alive 111 Dolly Varden ≥200 mm FL migrating upstream past the weir (Table 1). The upstream migration peaked during 12 August-1 September (Figure 4). The highest count of Dolly Varden migrating downstream occurred during the weeks of 7-20 October, the last weeks the weir was in operation (Figure 4). We captured 81 Dolly Varden migrating downstream; 95% of those were not recaptures (Table 2).

Of the 81 Dolly Varden captured migrating downstream only four had been tagged during the upstream migration, indicating that we captured only a small portion of the population at the weir. Since the assumptions for the abundance estimator were not met, the escapement estimate is a minimum, and is the sum of up migrating fish marked at the weir and unmarked fish captured moving downstream at the weir. The minimum spawning abundance is 192 Dolly Varden ≥200 mm (Table 1).

In 2000, most Dolly Varden captured at the weir were 400-549 mm (Table 3, Figure 5). There was no difference in length distribution between upstream and downstream fish (a = 0.05).

We did not observe any salmon spawning within Cooper Creek downstream of the weir. We passed 31 Dolly Varden <200 mm FL that were sampled but not tagged, 6 sockeye salmon, 2 coho salmon, 8 rainbow trout, and 3 round whitefish *Prosopium cylindraceum* upstream.

2001 STUDY

In 2001, the Cooper Creek weir was in continuous operation from 19 July through 19 October. The weir was removed on 19 October after ice submerged several of the floating panels and threatened to damage the weir structure. Creek water levels varied considerably throughout weir operation. Weir personnel made regular inspections of the weir to locate gaps soon after their formation. Temperature ranged from 0.0°C to 9.5°C. Average weekly temperature rose from July through August, then decreased sharply in October (Figure 4).

We captured and released alive 355 Dolly Varden ≥200 mm FL migrating upstream past the weir (Table 1). Upstream movement peaked during 16-22 September (Figure 4). We captured 115 Dolly Varden migrating downstream past the weir; 90% were not recaptures (Table 2). The downstream migration was still building during the week we removed the weir, and in fact, Dolly Varden were still moving upstream (Figure 4).

Again in 2001, the population was not closed. Fish were still entering the system at the same time other fish were leaving. Since the assumptions for the abundance estimator were not met, the escapement estimate is a minimum, and is the sum of up migrating fish marked at the weir and unmarked fish captured moving downstream of the weir. The minimum spawning abundance is 470 Dolly Varden ≥200 mm (Table 1).

Most Dolly Varden moving upstream in 2001 were in the 400-549 mm length categories (Table 3; Figure 5). There was no difference in length distribution between upstream and downstream fish (a = 0.05).

We did not observe any spawning salmon in Cooper Creek downstream of the weir. We captured 86 Dolly Varden <200 mm that were sampled but not tagged. Two Chinook salmon, 1 coho salmon, 3 sockeye salmon, 3 rainbow trout, 15 round whitefish, 2 grayling *Thymallus arcticus*, and 1 slimy sculpin *Cottus cognatus* were passed upstream through the weir.

DISCUSSION

In all 3 years of the study, we were unsuccessful at obtaining a census of the spawning population of Dolly Varden. In 1999, the first year of the study, we anticipated that Dolly Varden would enter Cooper Creek to spawn starting at the end of August, shortly after we installed the weir. However, the upstream migration had already started prior to weir installation (Figure 4). In 2000, we installed the weir in mid-July in an attempt to begin operations prior to the start of the upstream migration, but we still captured Dolly Varden moving upstream as soon as the weir was in place. In 2001, our attempts to install the weir in May were unsuccessful because of high water and flooding conditions. Upon installation in mid-July, we immediately began capturing upstream-migrating Dolly Varden. In all 3 years, the weir was removed prior to completion of the downstream migration. Therefore, we attempted to obtain an abundance estimate by conducting capture-recapture experiments, but because assumptions were violated, our only option was to use the weir counts as a minimum estimate of spawning abundance. We recognize that these are minimums, and do not include fish that we did not capture. Based on the large proportion of unmarked fish captured moving downstream, the actual spawning abundance of Dolly Varden in Cooper Creek is greater than our minimum estimates, but to what extent is unknown.

The high proportion of unmarked fish captured in the downstream migration (Table 2) could be due to a combination of several factors. First, it is clear that the weir was not fish tight because in all years there were multiple examples of Dolly Varden being caught consecutively in the same trap. This could have been due to high water allowing fish to travel either over the top of the weir or around it in the wooded area. In all study years, water levels varied considerably throughout weir operations, making it difficult to eliminate gaps between the weir and streambed, and to ensure complete coverage of the channel width. Therefore, erosion beneath the weir track and along the riverbank could have compromised the weir.

However, especially in 2001, we believe that erosion could not explain the remarkably large proportion of unmarked fish in the downstream migration because we made every attempt to ensure that the weir remained fish tight throughout the project by examining the weir daily for gaps. Therefore, we speculate that Dolly Varden eluded us by jumping over the top or maneuvering around the weir undetected. Researchers trying to use similar techniques for future projects should incorporate methods for evaluating this error source.

In addition, the high proportion of unmarked fish in the downstream migration could also be the result of a protracted upstream migration. In all 3 years of the study, Dolly Varden were captured as soon as the weir was in place, showing conclusively that Dolly Varden were already in Cooper Creek as early as mid-July. Although unlikely, another possible explanation for the high proportion of unmarked fish could be that Dolly Varden feed in spring and/or summer, or overwinter, in Cooper Creek. We would recommend sampling of upper reaches in early spring to rule out this possibility if future research is planned for this creek. Sampling should also be conducted in the upper reaches in October to verify that spawning of Dolly Varden is occurring there. More about the habits of Dolly Varden in Cooper Creek will be known when the companion radiotelemetry study is completed.

Dolly Varden sampled at the Cooper Creek weir were larger than Dolly Varden captured at a weir on the Anchor River in 1995 (Larson 1997). At the Anchor River, 63% of Dolly Varden captured moving

upstream were less than 400 mm, whereas at Cooper Creek, most Dolly Varden were 400 mm or larger.

ACKNOWLEDGEMENTS

Jerry Strait, David Atcheson, Dennis Reagen, Cindy Weeks, Greg Corner, Rob Massengill and Larry Nicholson made significant contributions to the data collection in this report. Their attention to the daily logistical details helped maximize sampling effort. The assistance of public volunteer Violetta Strait augmented the sample size considerably and her participation in the daily logistical details helped immensely.

REFERENCES CITED

Armstrong, R. H. 1965. Some migratory habits of the anadromous Dolly Varden *Salvelinus malma* (Walbaum) in southeast Alaska. Alaska Department of Fish and Game Research Report 3:1-36, Juneau

Armstrong, R. H. 1984. Migration of anadromous Dolly Varden charr in southeastern Alaska - A manager's nightmare. Pages 559-570 *in* L. Johnson, and B. L. Burns, editors. *Biology of the Arctic charr, Proceedings of the International Symposium on Arctic Charr; May 1981*. Univ. Manitoba Press, Winnipeg, Manitoba.

Behnke, R. J. 1980. A systematic review of the genus *Salvelinus*. Pages 441-480 *in* E. K. Balon, editor. *Charrs: salmonid fishes of the genus Salvelinus*. Dr. W. Junk Publishers, The Hague.

Cochran, W. G. 1977. Sampling techniques. Third Edition. John Wiley & Sons, New York.

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

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds96-32.pdf

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds95-24.pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-29(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds98-25(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-41(revised).pdf

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-8, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-08.pdf

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-11, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-11.pdf

Larson, L. 1995. A portable restraint cradle for handling large salmonids. North American Journal of Fisheries Management 15:654-656.

REFERENCES CITED (Continued)

Larson, L. L. 1997. Lower Kenai Peninsula Dolly Varden studies during 1995. Alaska Department of Fish and Game. Fishery Data Series No. 97-2, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds97-02.pdf

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1978-1979, Project F-9-11, 20 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-11(20)SW-I-A.pdf

Mills, M. J. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-12(21)SW-I-A.pdf

Mills, M. J. 1981a. Alaska statewide sport fish harvest studies - 1979 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-13(22a)SW-I-A.pdf

Mills, M. J. 1981b. Alaska statewide sport fish harvest studies - 1980 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-13(22b)SW-I-A.pdf

Mills, M. J. 1982. Alaska statewide sport fish harvest studies - 1981 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1981-1982, Project F-9-14, 23 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-14(23)SW-I-A.pdf

Mills, M. J. 1983. Alaska statewide sport fish harvest studies - 1982 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1982-1983, Project F-9-15, 24 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-15(24)SW-I-A.pdf

Mills, M. J. 1984. Alaska statewide sport fish harvest studies - 1983 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fis h Studies, Annual Performance Report 1983-1984, Project F-9-16, 25 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-16(25)SW-I-A.pdf

Mills, M. J. 1985. Alaska statewide sport fish harvest studies - 1984 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1984-1985, Project F-9-17, 26 (SW-I-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-17(26)SW-I-A.pdf

Mills, M. J. 1986. Alaska statewide sport fish harvest studies - 1985 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1985-1986, Project F-10-1, 27 (RT-2), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-10-1(27)RT-2.pdf

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-002.pdf

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-052.pdf

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-122.pdf

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds90-44.pdf

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds91-58.pdf

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds92-40.pdf

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds93-42.pdf

REFERENCES CITED (Continued)

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. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds94-28.pdf

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters. Second edition. Griffin and Company, Ltd. London.

Sonnichsen, S. 1990. Stock assessment of Dolly Varden in the Buskin River, Kodiak, Alaska 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-41, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds90-41.pdf

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds03-05.pdf