Fishery Data Series No. 06-57

Abundance of Cutthroat Trout in Auke Lake in 2003, and Dolly Varden and Cutthroat Trout Migrations at Auke Creek in 2004

by

Judith L. Lum

and

Sidney G. Taylor

November 2006

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 Department of Fish and Game	ADF&G
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. 06–57

ABUNDANCE OF CUTTHROAT TROUT IN AUKE LAKE IN 2003, AND DOLLY VARDEN AND CUTTHROAT TROUT MIGRATIONS AT AUKE CREEK IN 2004

by
Judith L. Lum
Alaska Department of Fish and Game, Division of Sport Fish, Douglas

and
Sidney G. Taylor
National Marine Fisheries Service, Auke Bay

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

November 2006

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C.777-777K) under Project F-10-19 and F-10-20, Job No. R-1-2.

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.

Judith L. Lum, Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA[a]

and

Sidney G. Taylor, National Marine Fisheries Service, Alaska Fisheries Science Center
Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801-8626 USA

[a] Author to whom all correspondence should be addressed: judy_lum@fishgame.state.ak.us

This document should be cited as:
Lum, J. L. and S. G. Taylor. 2006. Abundance of cutthroat trout in Auke Lake in 2003, and Dolly Varden and cutthroat trout migrations at Auke Creek in 2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-57, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The Auke Creek weir near Juneau, Alaska, was operated in 2004 to count migrating sea-run Dolly Varden *Salvelinus malma*, cutthroat trout *Oncorhynchus clarki*, and other species of Pacific salmon *Oncorhynchus spp*. The number of Dolly Varden emigrants, 3,955, was the lowest since 1985, and below the annual average of 6,211. The number of Dolly Varden immigrants, 2,564, was the lowest observed since accurate immigration counts for this species began in 1997. Average fork length of emigrant Dolly Varden was 244 mm (SD = 63). Emigrant and immigrant wild cutthroat trout counts were 136 and 91, respectively. Average fork length of emigrant cutthroat trout was 261 mm (SD = 38). Estimated abundance of cutthroat trout ≥180 mm in Auke Lake during 2003 was 414 (SE = 26) in spring 2003; this estimate falls between the estimates made in previous years.

Key words: Alaska, Auke Lake, Auke Creek, cutthroat trout, Dolly Varden, sea-run, weir, abundance, length, timing, PIT, VI, tag retention, population estimate, Jolly-Seber model.

INTRODUCTION

The Auke Lake system, north of Juneau, Alaska (Figure 1), has native populations of Dolly Varden *Salvelinus malma;* cutthroat *Oncorhynchus clarki* and steelhead trout *O. mykiss;* and pink *O. gorbuscha*, chum *O. keta*, sockeye *O. nerka*, and coho salmon *O. kisutch*. Since 1986, Chinook salmon *O. tshawytscha* have returned to Auke Creek as a result of releases of hatchery smolts in Auke Bay near the mouth of Auke Creek. A weir has been operated on Auke Creek, the outlet stream of Auke Lake, since 1962. A permanent structure was constructed in 1980, and in 1997 the weir was modified to capture all immigrant Dolly Varden and cutthroat trout in addition to several other species (Table 1).

The Auke Creek database on anadromous species is the longest and most complete in Southeast Alaska. The Alaska Department of Fish and Game (ADF&G) Division of Sport Fish, the University of Alaska, Fairbanks (UAF), and the National Marine Fisheries Service (NMFS) fund seasonal personnel to assist with studies at Auke Creek weir under an interagency cooperative agreement. Fish data collected at the weir are used as indicators of the status of local stocks and help to guide management decisions for the Juneau area.

Studies at Auke Creek weir have provided important insights into life history, behavior, age composition, maturity, run timing, and growth of fish present in the Auke Lake system (Lum et al. 1998-2002, 2004; Lum and Taylor. 2006a,b; Neimark 1984a,b; Taylor and Lum *Unpublished-a-g*).

DOLLY VARDEN

Dolly Varden have a very complex life history among salmonids (Armstrong and Morrow 1980), and new features are still being learned. Long-term trends in abundance, age structures, growth patterns, and migration timing for Dolly Varden populations in Alaska are largely unknown. Data from the Auke Creek weir will help to close this information gap, while providing managers an indication of Dolly Varden population status along the Juneau roadside as urban development in this area continues.

Dolly Varden are important in the local Juneau sport fishery (Tables 2 and 3), and Auke Lake provides important overwintering and rearing habitat for local Dolly Varden. Some spawning undoubtedly occurs in the lake system; however, spawner numbers and annual production of smolts remain unknown. Emigrant Dolly Varden at Auke

Table 1.–Average number of migrant fish counted at Auke Creek, 1980–2004.

Annual average	Pink salmon	Coho salmon	Sockeye salmon	Chum salmon	Chinook salmon	Dolly Varden	Cutthroat trout	Steelhead
Spring	108,920	6,125	17,234	4,012	0	6,211	255	8[a]
Fall	3,419	10,996	1,256	730	232[b]	4,276[a]	228[a]	3[a]

[a] Average of 1997–2004 weir counts, when these species were tallied.

[b] Chinook salmon captured at Auke Creek are killed at the weir.

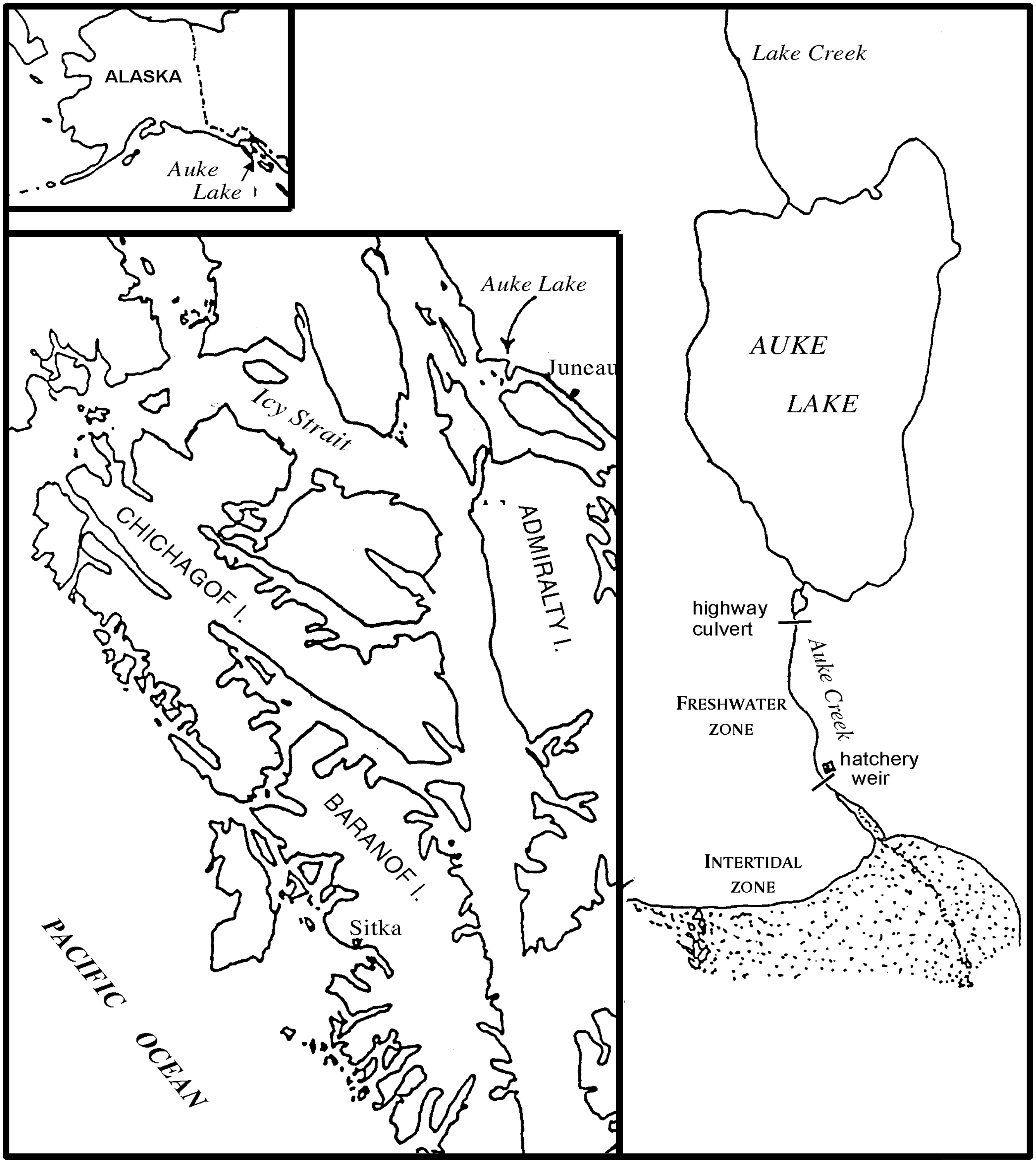


Figure 1.–The Auke Lake system in northern Southeast Alaska and location of the Auke Creek weir.

Table 2.–Estimates of sport fishing effort, total catch, and harvest of cutthroat trout and Dolly Varden in the Auke Creek drainage, 1990–2003.

					Cutthroat Trout		Dolly Varden[a]	
Year	Anglers	Trips	Days	Responses	Catch	Harvest	Catch	Harvest
1990	34	34	34	2	17	17	0	0
1991	16	33	23	1	0	0	0	0
1992	75	87	75	4	18	0	0	0
1993	50	325	271	4	391	224	49	0
1994	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
1995	29	32	29	1	26	0	0	0
1996	40	397	375	3	1,104	0	485	0
1997	45	47	47	2	16	0	54	0
1998	46	100	113	4	101	17	177	0
1999	33	12	33	1	9	0	0	0
2000	54	22	54	2	195	0	0	0
2001	86	307	353	5	807	24	216	0
2002	135	788	1,071	8	1,735	38	724	0
2003	17	25	25	1	0	0	56	0

Note: Estimates of catch and harvest were derived from small numbers of mail survey responses and are thus imprecise (Statewide Harvest Survey database, Alaska Department of Fish and Game, Division of Sport Fish/Research and Technical Services, Anchorage). Estimates based on fewer than 12 responses are only used to document sport fishing that has occurred and not used for assessing trends or any other analyses.

[a] Auke Lake is closed to the harvest of Dolly Varden.

[b] No estimates were made in 1994.

Table 3.–Estimates of sport fishing effort, total catch, and harvest of cutthroat trout and Dolly Varden in the marine areas surrounding Auke Creek, 1990–2003.

					Cutthroat Trout		Dolly Varden	
Year	Anglers	Trips	Days	Responses	Catch	Harvest	Catch	Harvest
1990	516	447	571	16	0	0	103	52
1991	294	343	322	13	0	0	12	12
1992	623	1,359	1,494	29	0	0	8	0
1993	1,862	3,416	3,860	99	0	0	76	0
1994	2,639	5,345	7,101	118	0	0	391	103
1995	2,273	3,471	5,225	97	0	0	109	61
1996	1,989	2,313	2,926	91	58	11	244	109
1997	1,577	2,142	2,944	66	28	0	998	197
1998	1,735	2,088	2,797	74	15	15	150	150
1999	1,847	2,445	3,885	81	67	29	654	97
2000	2,770	3,575	5,588	130	45	9	828	108
2001	2,429	3,916	4,841	115	12	0	486	43
2002	1,672	2,036	2,927	84	7	7	263	0
2003	2,122	2,037	3,419	75	127	37	0	0

Note: Included in the counts are boat and shore fishing in Auke Bay and boat and shore fishing near the mouth of Auke Creek. Estimates of catch and harvest derived from smaller numbers of survey responses are increasingly imprecise (Statewide Harvest Survey database, Alaska Department of Fish and Game, Division of Sport Fish/Research and Technical Services, Anchorage). Estimates based on fewer than 12 responses are only used to document sport fishing that has occurred and not used for assessing trends or any other analyses. Estimates based on responses of 12 to 29 can be useful to assess long-term trends.

Creek were counted in 1970 and since 1980 have been counted annually. There were 4 years in which all or most of the emigrant Dolly Varden were fin-marked or tagged when they were captured at Auke Creek weir. Emigrant Dolly Varden were also checked for missing fins and tags, and a subsample (or all) of the emigrants were measured to determine inter- and intra-annual changes in size.

CUTTHROAT TROUT

Coastal cutthroat trout have a life history that is characterized by a diversity of expressions within individuals and among populations. There can be resident and sea-run cutthroat trout in the same system. Resident cutthroat trout spend time in a riverine or lacustrine phase before migrating into inlet streams to spawn, never leaving the freshwater system. Sea-run cutthroat trout typically spend several years in a resident, riverine, or lacustrine phase before migrating to and residing in marine waters for a period of up to a few months. They return to freshwater to spawn or overwinter, and may repeat this cycle (or a variation) one or more times (Northcote 1997; Trotter 1997). Comprehensive time series of data on the distribution, abundance, age structure, growth, and migration timing for this species are rare, as they are for Dolly Varden. Such data are important to understanding the impact that directed fisheries can have on small populations of cutthroat trout (Behnke 1979; Spense 1990; Wright 1992).

Cutthroat trout are caught in Auke Lake through the ice during the winter and from the beach or boats during the remainder of the year (Table 2, Table 3). Anecdotal information suggests that the cutthroat trout fishery in Auke Lake was more productive than at present. Strategic planning exercises conducted by ADF&G in 1989 identified improvement of the cutthroat trout fishery in Auke Lake as a goal to help satisfy the demand for sport fisheries along the Juneau roadside (Schwan 1990). The current research program grew from that planning exercise. The result of this effort is the longest and most complete data set across the range of the species.

Starting in 1981, mature cutthroat trout taken from Auke Creek were spawned and the resulting progeny reared in the Auke Creek Hatchery and later stocked into Auke Lake with a variety of fin clips. Marked fish were released in Auke Lake in 1983, 1986, 1987, 1991, and in 1994 (Table 4). The program was ended by the ADF&G in 1994 after the release of the 1993 brood year. Hatchery marked cutthroat trout were last seen at the Auke Creek weir in 1999 and in Auke Lake during the lake study for the same year. Except for harvest data (Tables 2 and 3), the data in this report pertains to wild fish; any hatchery raised and marked fish captured in the lake or at the weir was censored from data summaries used to compile this report.

Table 4.–Summary of the brood year releases of hatchery raised cutthroat trout and number of respective recoveries at the Auke Creek weir.

Brood year	Total released	Mark type	Release date	Avg. size (mm)	Avg. weight (gm)	Total recoveries	Recoveries earliest	Recoveries latest	% Recovery (smolts)
1981	1,286	RV	4/26/1983	120	21	142	1983	1988	11%
1982	4,078	LV	8/02/1983	96	10	138	1984	1992	3%
1985	3,489	AD	11/21/1986	129	22	1,131	1987	1993	32%
1986	1,719	AD	8/21/1987	140	25	220	1988	1993	13%
1991	2,465	RV	11/06/1991	68	3.6	64	1993	1997	3%
1993	3,098	LV or RV	6/15/1994	94	8.3	217	1995	1999	7%

The first significant wild-trout tagging program at Auke Creek began in 1994 when fish leaving Auke Lake were captured and tagged with visual implant (VI) at the weir. This was followed with the implementation of passive integrated transponder (PIT) tagging at the weir in 1997.

Anglers in marine waters recovered tagged fish leaving Auke Lake for several years following spring 1997 (the first year of PIT tagging at the weir), showing that Juneau roadside fisheries for anadromous cutthroat trout (Table 3) partly depended on stocks that overwinter or reside in Auke Lake. After a pilot study in 1997, a mark-recapture program to estimate annual spring or summer abundance in Auke Lake began in 1998.

Trout research at Auke Creek and Auke Lake, particularly the PIT-tagging program started in 1997, has yielded valuable and unique information from an anadromous cutthroat trout system. Tracking the migration histories of individual fish in and out of the lake allows us to describe use of the lake as an anadromous rearing area. Recoveries of tagged fish in local fisheries yield data on saltwater migration patterns and the opportunity to observe the intra- and inter-annual movements between and within watersheds. As urbanization spreads in the Juneau area, these results will help us recognize critical habitats and document effects of habitat change.

OBJECTIVES

The purpose of this report is to summarize counts and biological characteristics of Dolly Varden and cutthroat trout at the Auke Creek weir in 2004, and estimate abundance of cutthroat trout residing in Auke Lake in 2003 using a multi-event Jolly-Seber model. Our objectives were to:

1. Count all cutthroat trout and Dolly Varden leaving Auke Lake, March through June 2004;
2. Measure fork length (FL) of each cutthroat trout, and estimate the mean FL of Dolly Varden leaving Auke Lake, March through June 2004;
3. Count all cutthroat trout and Dolly Varden entering Auke Lake from July through October 2004;
4. Measure FL on each cutthroat trout entering Auke Lake, July through October 2004;
5. Estimate the abundance and annual mortality of cutthroat trout residing in Auke Lake during spring 2003.

STUDY SITE

The Auke Lake system is a mainland watershed of 1,072 ha located approximately 19 km north of downtown Juneau, Alaska on the Juneau road system. Auke Lake has a surface area of 67 ha and is fed by five tributaries. Lake Creek is the largest tributary with a watershed of 648 ha. The maximum depth of Auke Lake is 31 m, and the surface elevation is approximately 19 m (Figure 2). Auke Creek weir is located about 400 m downstream from the lake at the head of tidewater at Auke Bay (Figure 1). The shoreline of Auke Lake is bordered by forested terrain, which varies from gentle slopes to steep-sided banks. The shoreline zone of water consists of areas dominated by emergent vegetation of *Equisetum* spp. and *Nuphar* spp., and other areas are characterized by large numbers of submerged and floating conifers anchored to the lakeshore and bottom by large root wads. At least 50% of the shoreline has been urbanized by residential development, along with portions of the streambanks along inlet streams.

METHODS

EMIGRANT POPULATIONS

The Auke Creek weir was installed March 2 and operated through June 30, 2004, to intercept all emigrant salmonids. During this time, fish could not move upstream through the weir. The weir was designed to spill water through five inclined traps and vertical aluminum panels covered with 3-mm perforations that are effective at both high and low flows. Fish and water that exited the inclined traps were diverted through an aluminum trough to a fiberglass holding tank downstream from the weir. A separate water source supplied the holding tank. Fish were sorted by species, counted, sampled, and tagged each day and released the following morning. Cutthroat trout were not anesthetized before tagging.

All Dolly Varden were counted and examined for tags and fin marks. Every 10th Dolly Varden handled was measured to the nearest 5 mm FL. The fraction p_k of Dolly Varden in 20 mm size increments (k) emigrating from Auke Lake was estimated:

$$\hat{p}_k = \frac{n_k}{n} \qquad (1)$$

The variance of $\hat{p}_k$ was estimated:

$$\text{var}(\hat{p}_k) = (1 - \frac{n}{N})\frac{\hat{p}_k(1 - \hat{p}_k)}{n - 1} \qquad (2)$$

where n is the number sampled for length and N is the weir count. The standard error of p_k was estimated:

$$S\hat{E}(\hat{p}_k) = \sqrt{\text{var}(\hat{p}_k)} \qquad (3)$$

The abundance N_k of Dolly Varden by size increment was estimated:

$$\hat{N}_k = \hat{p}_k(N) \qquad (4)$$

The variance of $\hat{N}_k$ was estimated:

$$\text{var}(\hat{N}_k) = N^2\left[\text{var}(\hat{p}_k)\right] \qquad (5)$$

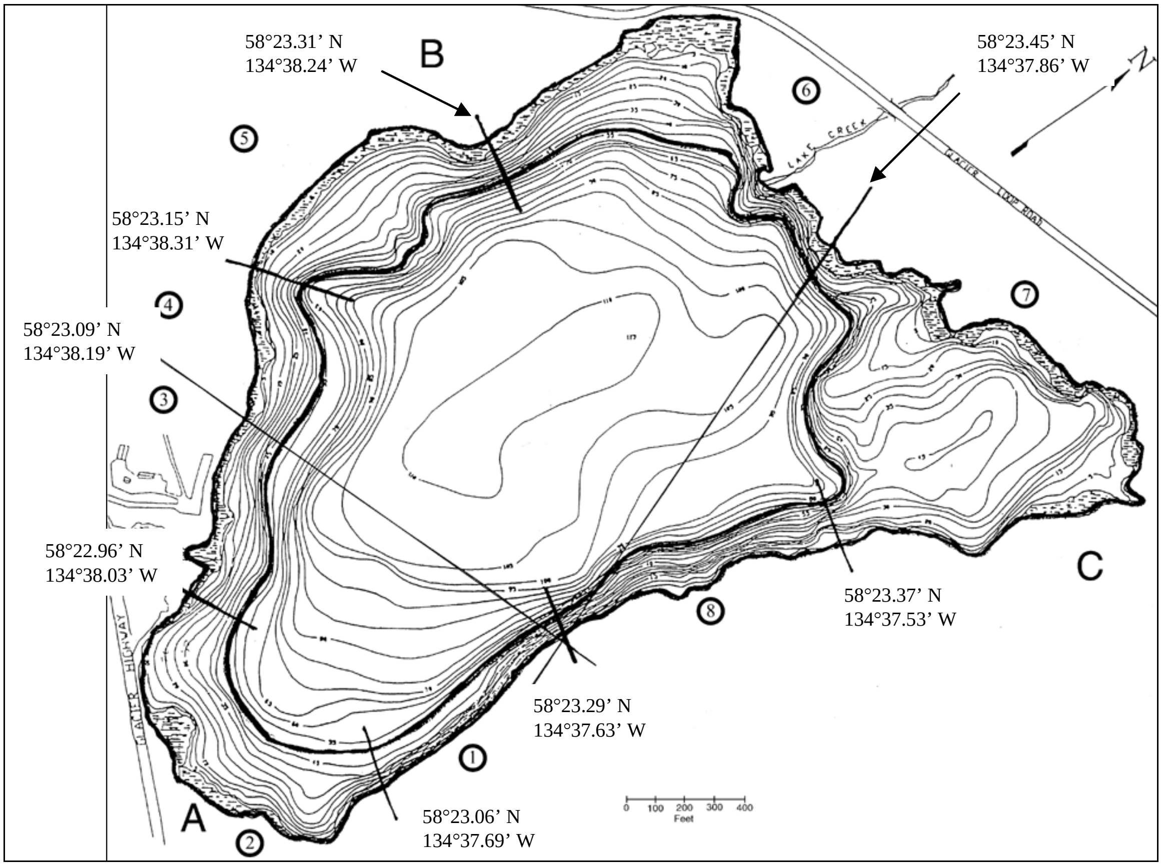


Figure 2.–Bathymetric map of Auke Lake showing location of sampling areas in 2004. The lake area inside the inner bold line denotes depths >15 m that were excluded from sampling. The two intersecting straight lines indicate the separation between the three strata (A, B, and C) used in analysis.

where *n* is the number sampled for length and *N* is the weir count. The standard error of $\hat{N}_k$ was estimated:

$$S\hat{E}(\hat{N}_k) = \sqrt{\text{var}(\hat{N}_k)} \qquad (6)$$

Average length of the Dolly Varden emigrants sampled at the weir was estimated:

$$\bar{y} = \frac{1}{n}\left(y_1 + y_2 + ... + y_n\right) = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad (7)$$

where n is the number sampled for length. The standard error of $\bar{y}$ was estimated as:

$$S\hat{E}(\bar{y}) = \sqrt{\left(1-\frac{n}{N}\right)\frac{1}{n*(n-1)}\sum_{i=1}^{n}\left(y_i-\bar{y}\right)^2} \qquad (8)$$

where N is the weir count. The finite population correction factor (fpc) 1-n/N is included because of the exactly known and relatively high sampling rate.

All cutthroat trout were counted, measured to the nearest mm FL and examined for adipose clips, dye marks, and the presence of a PIT tag that would have been injected between 1997 and 2004. All cutthroat trout missing an adipose fin were checked with an electronic scanner for a PIT tag. Each PIT tag has a unique 10 character alphanumeric code or number. Before 2000, PIT tags were inserted under the skin in the dorsal sinus, next to the basal fin rays of the dorsal fin. Starting in 2000, tags were inserted under the skin immediately posterior and parallel to the midpoint of the cleithrum. This tag location was chosen to help fishermen find the tag when cleaning their fish. All unmarked, emigrant cutthroat trout were PIT-tagged, adipose fin clipped, and given red photonic dye mark on the anal fin before release. One or two drops of cyanoacrylate (super glue) were used to cover the PIT tag insertion wound to prevent tag loss and infection. Newly tagged cutthroat trout were held for 24 hours to evaluate short-term tag loss and handling mortality.

All cutthroat trout mortalities were measured, inspected to determine sex, sampled to collect scales and otoliths, and screened for PIT tags, which were removed if present. Scales from cutthroat trout mortalities were taken from the left side of the caudal peduncle immediately above the lateral line (Brown and Bailey 1949; Laakso and Cope 1956). Each fish was wiped with the blunt side of a knife to remove excess mucus before collecting a sample of scales. A sample of 15 to 20 scales from each fish was spread on a microscope slide so that no scales were overlapping, and sandwiched between another glass slide (Ericksen 1999). The slides were stored in a labeled coin envelope inscribed with the sample number and date. Otoliths were stored dry in plastic or glass vials, and placed in the labeled envelope with the scales.

IMMIGRANT POPULATIONS

The weir was converted to count immigrants on June 30 and operated through October 31. Vertical slotted aluminum panels, 90 x 178 cm long, were inserted into the weir structure to divert adult salmon into the weir trap without restricting water flow. Perforated aluminum plates 45 x 90 cm long with 1.5 x 10 cm horizontal slots were placed on the bottom half of the lowest weir panels to prevent passage of small Dolly Varden and cutthroat trout. Before 1997, small fish passed through the weir panels and were not counted. Subsequently, two traps 1.5 x 2.4 x 0.8 m high were attached to the upstream side of the weir to capture small fish. Pickets on the trap entrances were spaced 2.5 cm apart to prevent larger salmonids from entering these traps. Square mesh plastic netting with 6 mm x 6 mm openings was used to cover the walls of the traps for small fish and adults.All immigrant Dolly Varden and cutthroat were counted and released upstream, except that early in the immigration, cutthroat might be released below the weir to reduce the incidence of injury and death associated with low stream flows, high temperatures, and poor osmoregulation (Lum et al. 1998). Thus, timing data for early immigrants can be slightly biased. Dolly Varden were examined for adipose fin clips and Floy tags from other studies, and marked fish were measured to the nearest 5 mm FL to estimate growth. Cutthroat trout were measured to the nearest 1 mm FL and examined for marks. Cutthroat missing their adipose fins were checked for dye marks on all fins and scanned for the presence of a PIT tag. Unmarked cutthroat trout were marked with a red dye on the anal fin but not PIT-tagged because high levels of mortality could result (ADF&G unpublished data from 1996).

Marine growth and residence of cutthroat trout leaving Auke Creek in 2004 was determined from individual PIT-tagged fish. Marine growth (mm and mm/day) of individual fish with a PIT tag was calculated as the increase in FL between emigration and immigration. Marine residence of cutthroat trout was defined as the number of days between emigration and immigration at Auke Creek, recognizing that some fish probably did not spend the whole period in saltwater.

All cutthroat trout found dead during the immigration period were processed in the same manner as during emigration. Dead fish that had a PIT tag were examined for scarring or encysting, tag placement, and movement of the tag.

CUTTHROAT TROUT IN AUKE LAKE

Sampling to estimate abundance, survival, and birth rates of cutthroat trout ≥180 mm FL in Auke Lake using the “full” Jolly-Seber (JS) model (Seber 1982) was conducted annually from 1998 to 2004. This JS analysis was made with data pooled by sampling year to yield a 7-event model having k-2 abundance estimates and k-2 survival rate estimates (k = number of sampling events). Fish captured several times during a sampling year were treated as being caught only once. Data for the analysis were collated in Statistical Analysis Software (SAS 1990) and an electronic spreadsheet, and analyzed with POPAN (Arnason et al. 1998) to estimate population parameters and obtain capture histories. Program JOLLY (Pollock et al. 1990) was used to obtain goodness-of-fit (GOF) statistics for the JS model.

In 1998, sampling was conducted by three separate trips made in July and August (Lum et al. 1999). In subsequent years, two trips were made in 1999 between May and June (Lum et al. 2000), two trips were made in 2000 in May (Lum et al. 2001), one trip was made in 2001 in April (Lum et al. 2002), and one trip was made in June in 2002 (Lum and Taylor 2004), 2003 (Lum and Taylor. 2006b), and 2004 (Lum and Taylor. 2006a). As sampling dates became earlier in 1999, and especially in 2001, emigrations of anadromous trout were not completed before the start of lake sampling. In 2002 through 2004, sampling was scheduled during June to follow the anadromous emigration and precede summer conditions characterized by water temperatures dangerous to fish captured and tagged in the study.

Cutthroat trout were captured using two types of traps baited with Chinook salmon eggs. Fifteen traps were plastic-mesh cylindrical devices 1 m long x 0.5 m diameter with a funnel entrance at each end and were referred to as “large traps” (Rosenkranz et al. 1999). One trap was a nylon-mesh, cylindrical “hoop” trap 2 m long x 0.5 m diameter. When fishing, the rings of the hoop trap were attached to 12 mm x 2 m metal conduit to hold the trap in the cylindrical shape. There was a funnel entrance at one end of the hoop trap, and the opposite end, where fish would be trapped, was closed with twine and large binder clamps. Trap soak-times were typically 22 to 24 hours.

The use of hook-and-line fishing was discontinued after 2002 because of extremely low catch rates. Captured trout were inspected for tags or marks and measured to the nearest mm FL. Fish missing their adipose fin were scanned to determine PIT tag number. Unmarked cutthroat trout ≥180 mm FL were tagged with a uniquely numbered PIT tag, given a red dye mark on the left ventral fin, and had their adipose fin excised. Fish caught more than once during the sampling year were treated similarly (except for tagging) and “recapture” was noted in comments. Trout were handled without using anesthesia and released in the area where they were captured.

The lake was divided into eight areas to facilitate sampling and accurate recording of locations where cutthroat trout were captured (Figure 2). Data from these areas were then pooled into three strata (A, B, C) for testing experimental assumptions. Trapping was conducted only in areas ≤15 m deep because previous work in Auke Lake showed trout were not captured at greater depths during the summer (Lum and Taylor 2004). All traps were fished each day and a fathometer was used to determine depth. Overall fishing effort (number of traps set) in each area was proportional to the lake surface area where depth was ≤15 m (Table 5). The depth, sampling area, and number of fish caught were recorded by trap set.

Table 5.–Distribution of sampling effort in Auke Lake by area in 2004. Sampling effort was uniformly distributed across each of the eight areas (Figure 2) of the lake in direct proportion to the amount of lake surface (≤15m depth) present, given a goal of deploying 144 traps over the 9-day sampling trip.

Area No.	Analysis stratum	Area[a] (km^2)	Proportion [a]	No. of traps set each day	Total trap effort (sets)
1	A	0.5463	0.0459	1	9
2	A	2.6098	0.2195	3–4	29
3	A	1.0583	0.0890	1–2	18
4	B	0.8275	0.0696	1	9
5	B	1.4691	0.1236	2	18
6	B	1.4562	0.1225	2	18
7	C	3.1297	0.2632	4	36
8	C	0.7932	0.0667	1	9
Totals		11.8901	1.0000	16	146

[a] Tabulated area and proportions are estimates for 0-15 m depths.

Assumptions of the standard (full) JS model (Seber 1982) include:

1. Every fish in the population has the same probability of capture in the i^{th} sample;
2. Every marked fish has the same probability of surviving from the i^{th} to the $(i+1)^{th}$ sample and being in the population at the time of the $(i+1)^{th}$ sample;
3. Every fish caught in the i^{th} sample has the same probability of being returned to the population;
4. Marked fish do not lose their marks between sampling events and all marks are reported on recovery; and
5. All samples are instantaneous (sampling time is negligible).

A two-component GOF test (Pollock et al. 1990) was used to evaluate the assumptions of homogeneous capture and survival probabilities. The first component of the GOF test is equivalent to the Robson (1969) test for short-term mortality, and the second test component is better at detecting heterogeneous survival probabilities (Pollock et al. 1990). The sum of the chi-squares from each component forms an omnibus test for violations of the first three assumptions listed above, i.e. equal probability of capture, survival, and return to the population. If these GOF statistics were significant, a generalization of the JS model, which allows survival rates for newly captured animals and previously captured animals to differ ("Analysis 3" in POPAN, "Model 2" in JOLLY), was considered. Heterogeneity by capture history (via the GOF test detailed above) has been observed in previous JS analyses at Auke Lake: fish caught for the first time in sample *i* have been *more* likely to be recaptured than fish tagged in previous years (Lum and Taylor 2004).

The condition that the probability of capture is the same for all fish within a sampling event can be waived (with respect to sampling location) if marked and unmarked fish mix completely between sampling events (Seber 1982). Complete mixing was evaluated by comparing the marked fractions (R/C, where R is the number of recaptures and C is the number of captures irrespective of gear) of fish caught in strata A, B and C, using fish that were marked the previous year. If (R/C)A = (R/C)B = (R/C)C complete mixing was indicated; otherwise, mixing was incomplete. A chi-square statistic (from a 2 x 3 contingency table, $\alpha = 0.05$) was used for the test. Complete mixing has been observed ($P < 0.05$) between all successive sample years since 1999 (Lum and Taylor. 2006a, b).

The equal probability of capture assumption will also be violated if sampling is size selective. Considerable experience with sampling gear used at Auke Lake shows that our gear is not significantly size selective for fish ≥180 mm FL (Lum et al. 1999, 2000).

The assumption that all fish have the same chance of surviving from the i^{th} to the $(i+1)^{th}$ sampling implies the absence of significant age or size dependent mortality rates for cutthroat trout ≥180 mm FL. We do not have an experimental design to test for this, but note that age-dependent mortality could occur in our population (Lum and Taylor. 2006a, b).

Assumption 3 was evaluated by direct examination of the capture histories (mortality status by year) from each event. Historically, the number of fish killed or released alive without tags has been very low (<1%). Assumption 4 was addressed by double marking trout with different combinations of fin clips and photonic dye marks each year and estimating the annual rate of tag loss. Because individual sampling trips spanned but 9 days, significant violations of assumption 5 were not expected. However, a large emigration or mortality during sampling would contribute to violation of this assumption.

The fraction p_k of cutthroat trout in 20-mm size increments in Auke Lake was estimated:

$$\hat{p}_k = \frac{n_k}{n} \qquad (9)$$

and the variance of $\hat{p}_k$ was estimated:

$$\hat{\mathrm{var}}(\hat{p}_k) = (1 - \frac{n}{\hat{N}}) \frac{\hat{p}_k (1 - \hat{p}_k)}{n - 1} \qquad (10)$$

where n is the number of fish measured for length and n_k is the subset of n that belong to length group k. A fpc was included in the variance equation because of the high sampling rate and availability of an abundance estimate $\hat{N}$ from the mark-recapture experiment. The standard error of p_k was estimated:

$$S\hat{E}(\hat{p}_k) = \sqrt{\hat{var}(\hat{p}_k)} \quad (11)$$

The abundance of cutthroat trout by size increment N_k was estimated:

$$\hat{N}_k = \hat{p}_k\left(\hat{N}\right) \quad (12)$$

The variance of $\hat{N}_k$ was estimated:

$$\hat{var}(\hat{N}_k) = \hat{N}^2\, var(\hat{p}_k) + \hat{p}_k^2\, \hat{var}(\hat{N}) - \hat{var}(\hat{N})\, var(\hat{p}_k) \quad (13)$$

The standard error of $\hat{N}_k$ was estimated:

$$S\hat{E}(\hat{N}_k) = \sqrt{\hat{var}(\hat{N}_k)} \quad (14)$$

RESULTS

DOLLY VARDEN MIGRATIONS IN 2004

The 2004 Dolly Varden emigration of 3,955 fish at Auke Creek was the lowest since 1985 and well below the 1980–2003 average of 6,305 (Table 6; Figure 3). The first Dolly Varden was captured March 23 and the last June 7 (Figure 4; Appendix A1). The midpoint of the emigration, May 4, was 5 days earlier than the 1980–2003 average of May 9 (range April 30 to May 24; Table 6). The peak count also occurred on May 4. The length of emigrant Dolly Varden averaged 244 mm FL (range 105 to 500 mm FL), and had a standard deviation of 63 mm. The weekly average length of Dolly Varden declined from near 350 mm FL in early-April to near 175 mm FL in mid-May (Figure 5). For all weeks following the midpoint, weekly average lengths were less than the annual average length for the emigration. A summary of abundance by size category shows about 22% of the emigration was <200 mm, 61% was between 200 and 300mm, and 17 % was > 300 FL. Less than 1% of the Dolly Varden emigration in 2004 was >400 mm (Table 7; Figure 6).

The Dolly Varden immigration of 2,564 fish began on July 28, and the last fish was captured October 25 before the weir was removed (Figure 4; Appendix A2). This was the lowest count since upstream migration of Dolly Varden was first monitored in 1997, and well below the 1997–2003 average of 4,250 (Table 6). Peaks in immigration occurred intermittently in mid- to late-September following heavy rainfall. The midpoint of immigration in 2004 was September 18, and the average midpoint date of immigration, 1997–2003 is September 8.

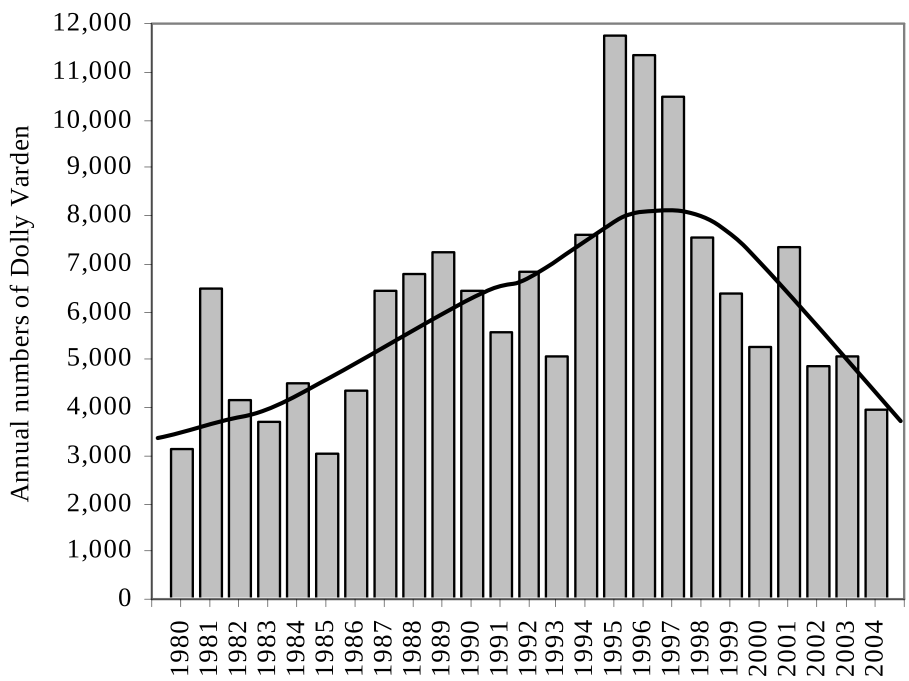


Figure 3.–Annual spring emigration of Dolly Varden at Auke Creek. The solid trend line was generated using local regression.

Table 6.–Annual counts and midpoint dates of the migrations of Dolly Varden and cutthroat trout at Auke Creek, 1980–2004.

	Dolly Varden				Cutthroat trout			
	Emigration		Immigration		Emigration		Immigration	
Year	No.	Date	No.	Date	No.	Date	No.	Date
1980	3,110	13-May			85	18-May		
1981	6,461	5-May			157	14-May		
1982	4,136	24-May			157	31-May		
1983	3,718	7-May			149	15-May		
1984	4,512	8-May			198	14-May		
1985	3,052	14-May			112	21-May		
1986	4,358	13-May			99	24-May		
1987	6,443	6-May			250	17-May		
1988	6,770	30-Apr			294	9-May		
1989	7,230	8-May			259	18-May		
1990	6,425	8-May			417	11-May		
1991	5,579	17-May			237	20-May		
1992	6,839	4-May			219	16-May		
1993	5,074	8-May			174	14-May		
1994	7,600	4-May			422	13-May		
1995	11,732	9-May			412	13-May		
1996	11,323	4-May			462	7-May		
1997	10,506	7-May	5,705	11-Sep	418	12-May	467	19-Sep
1998	7,532	1-May	4,993	4-Sep	336	11-May	361	14-Sep
1999	6,393	14-May	4,709	13-Sep	341	16-May	205	26-Sep
2000	5,254	6-May	3,665	5-Sep	249	13-May	105	4-Oct
2001	7,356	12-May	4,249	4-Sep	337	20-May	228	18-Sep
2002	4,858	12-May	4,341	9-Aug	210	20-May	241	20-Sep
2003	5,067	3-May	3,978	2-Sep	254	11-May	129	26-Sep
2004	3,955	4-May	2,564	18-Sep	136	10-May	91	22-Sep
Average	6,305	9-May	4,520	8-Sep	260	15-May	248	22-Sep

Note: The averages do not include 2004 data.

Table 7.–Length composition and estimated abundance at length for emigrating Dolly Varden at Auke Creek in 2004. Number sampled (nk), proportion ($\hat{p}_k$), abundance ($\hat{N}_k$), and standard error ($\hat{SE}$) are shown for each 20-mm length class.

Length *k*, mm FL	n_k	$\hat{p}_k$	$\hat{SE}(\hat{p}_k)$	$\hat{N}_k$	$\hat{SE}(\hat{N}_k)$
0-100	0	0.000	0.000	0	0.0
101-140	23	0.053	0.010	211	40.5
141-160	26	0.060	0.011	238	42.9
161-179	24	0.056	0.010	220	41.3
180-200	23	0.053	0.010	211	40.5
201-220	57	0.132	0.015	522	61.0
221-240	77	0.179	0.017	705	69.0
241-260	53	0.123	0.015	485	59.1
261-280	46	0.107	0.014	421	55.6
281-300	30	0.070	0.012	275	45.8
301-320	22	0.051	0.010	201	39.6
321-340	19	0.044	0.009	174	37.0
341-360	13	0.030	0.008	119	30.8
361-380	9	0.021	0.007	82	25.7
381-400	4	0.009	0.004	37	17.3
401-420	3	0.007	0.004	27	15.0
421-440	2	0.002	0.002	18	8.7
441-460	0	0.000	0.000	0	0.0
461-480	0	0.000	0.000	0	0.0
481-500	1	0.002	0.002	9	8.7
	n =432			N =3,955	

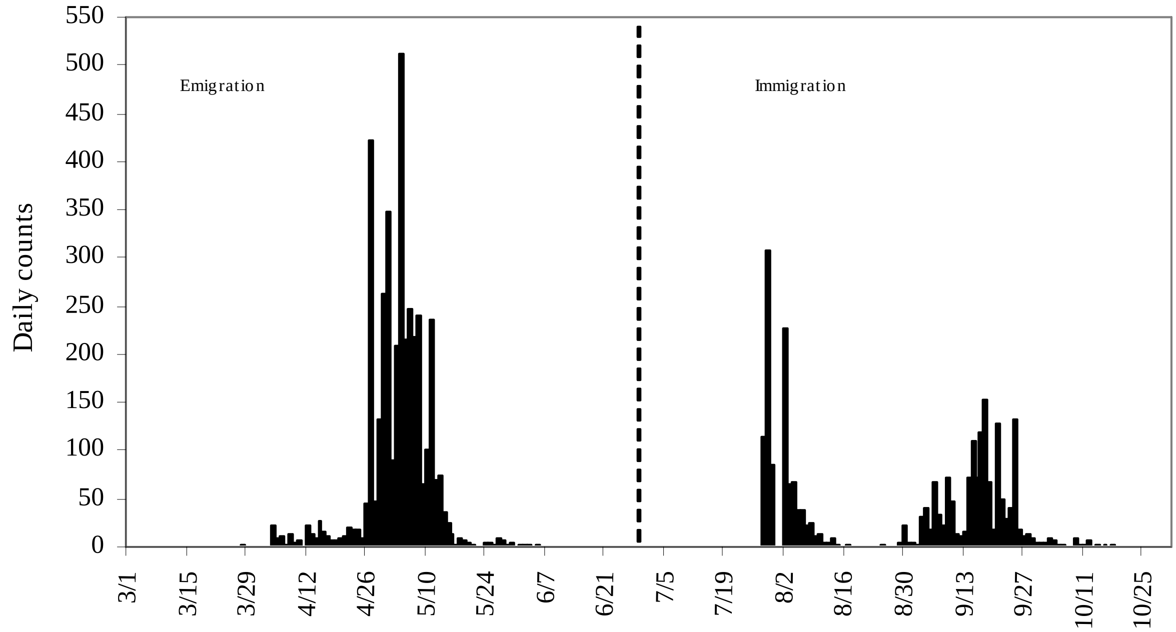


Figure 4.–Emigration and immigration counts of Dolly Varden at Auke Creek in 2004. The vertical dashed line marks June 30, when the weir was converted to count fall immigrants.

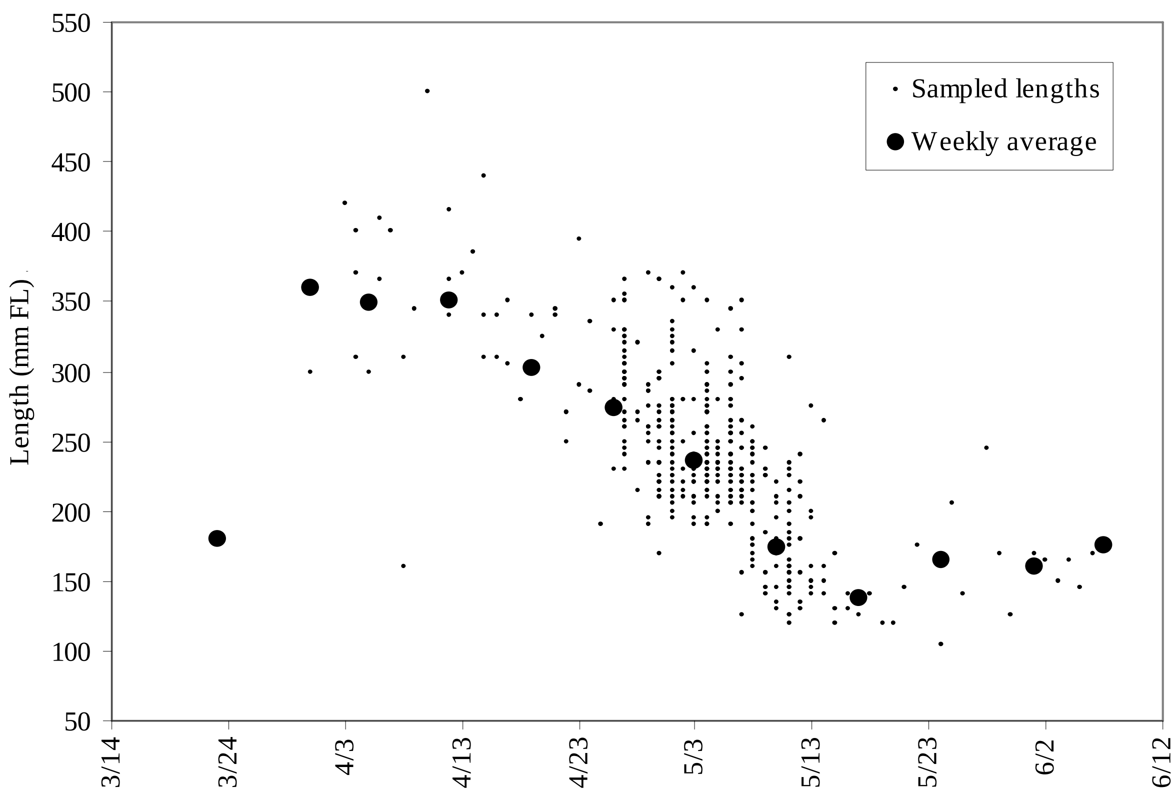


Figure 5.–Dolly Varden length (mm FL) versus date during the spring emigration at Auke Creek in 2004. The larger data point represents the average size of all fish within a migration week.

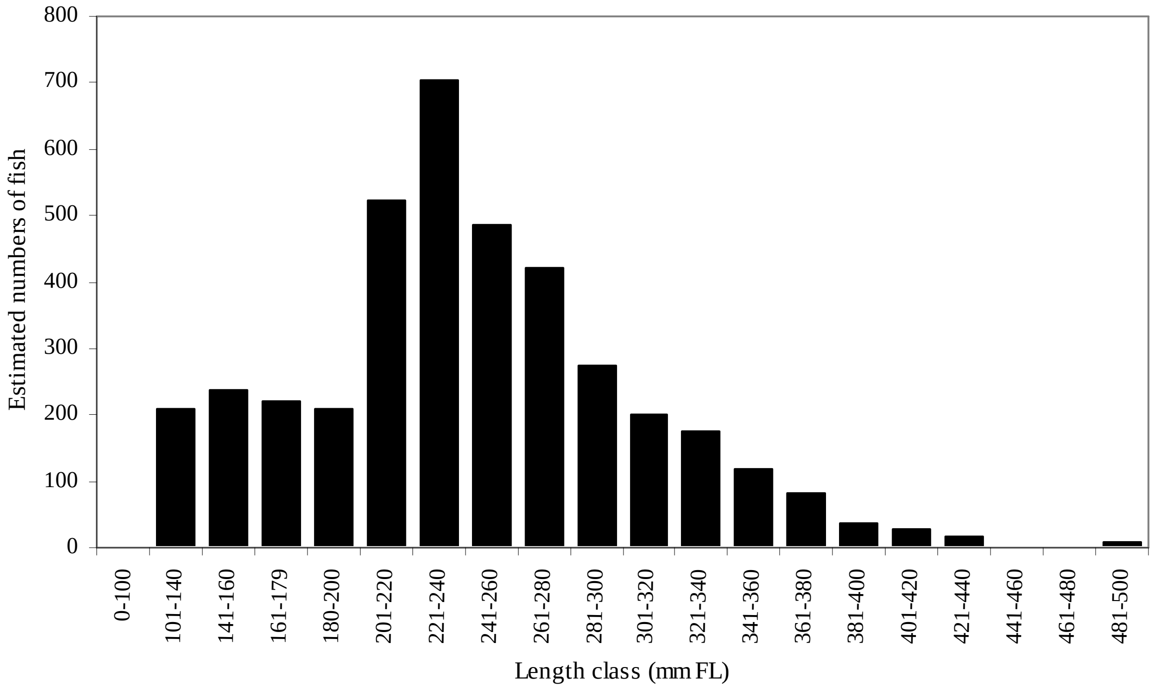


Figure 6.–Estimated abundance of emigrating Dolly Varden at Auke Creek in 2004. Estimated abundance at length are shown for 20-mm length class.

CUTTHROAT TROUT MIGRATIONS IN 2004

A total of 136 emigrant cutthroat trout passed the weir in 2004, well below the 1980–2003 average of 260 wild fish (Table 6, Figure 7). One of these emigrants died during tagging and one was released without a PIT tag. The emigration included 37 fish missing their adipose fin and 99 unmarked fish. Of the 37 recaptures, 24 were previously tagged and adipose fin clipped at the weir in 2003 or during earlier emigrations, and 13 were tagged in Auke Lake in 2002 and 2003. The 13 fish tagged in Auke Lake were making their first emigration to salt water in 2004.

The first emigrant was captured March 20 and the last, June 10 (Figure 8, Appendix A1). The midpoint of emigration (May 10) was 5 days earlier than the 1980–2003 average of May 15 (range May 7 to May 31, Table 6). Water temperatures during the emigration in 2004 ranged between 2.3° and 16.4°C. Overall, water temperatures were above average through May and June.

In general, the larger cutthroat trout emigrate earliest at Auke Creek, and the average weekly FL decreased about 40 mm between mid-April and mid-May (Figure 9). The average FL of all wild cutthroat emigrants in 2004 was 261 mm FL (range 124 to 370 mm FL) and the standard deviation of length was 38 mm. We attempted to determine the sex of individual cutthroat trout during the emigration. Most fish (64%) showed no obvious signs of gender (extruded vent or release of gametes upon capture, while 20% were clearly male and 16% were clearly female. Gender (extruded vent/gamete release) was most obvious early in the emigration, and obvious

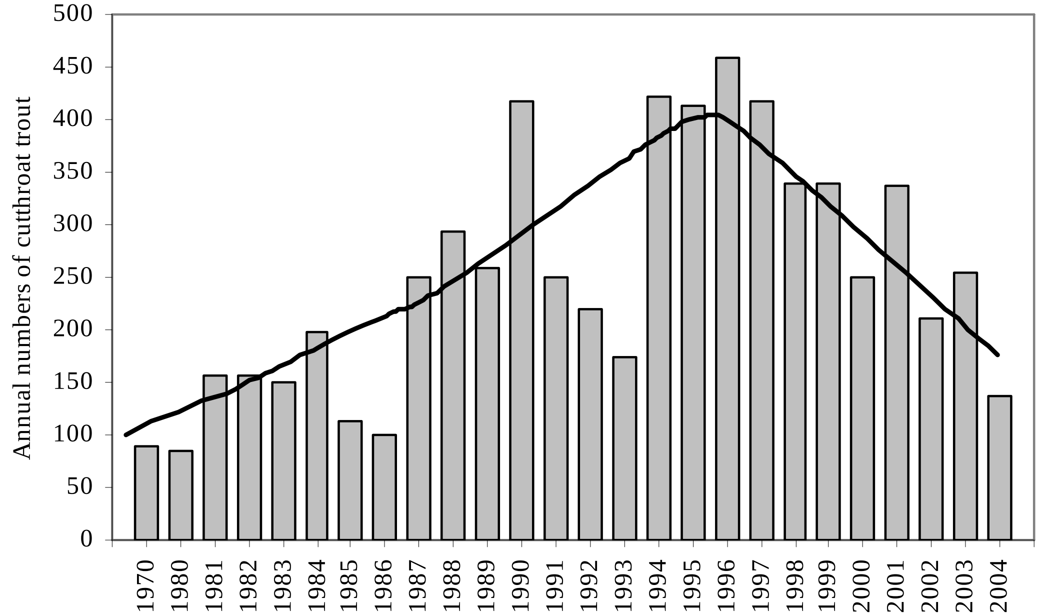


Figure 7.–Annual spring emigration of cutthroat trout at Auke Creek. The solid trend line was generated using local regression.

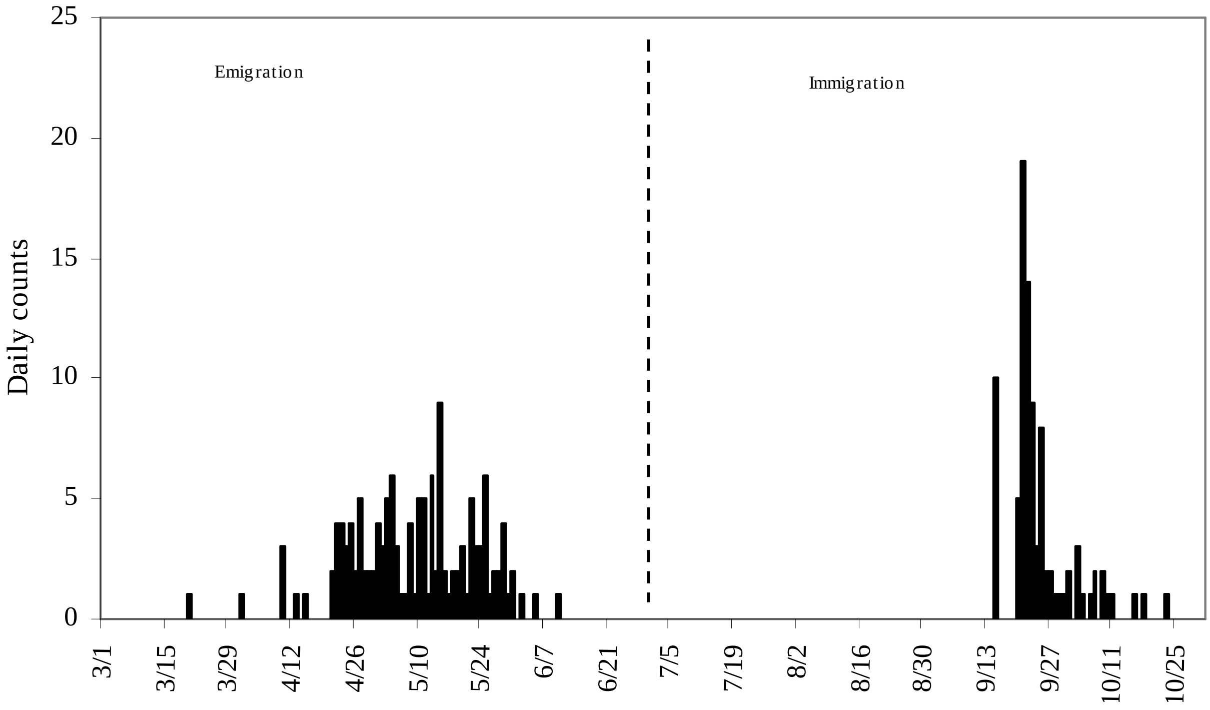


Figure 8.–Spring emigration and fall immigration counts for cutthroat trout at Auke Creek in 2004. The vertical dashed line marks June 30, when the weir was converted to count fall immigrants.

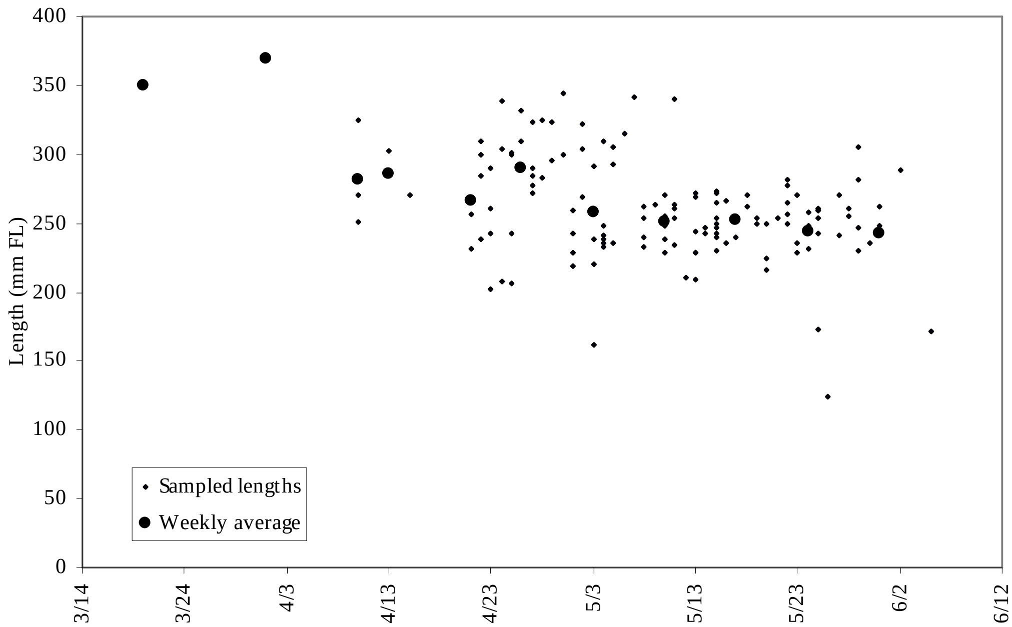


Figure 9.–Cutthroat trout lengths (mm FL) by date during the spring emigration at Auke Creek in 2004. The large data point represents the average size of fish in a migration week.

gravidity declined after the first week of May with the last ripe fish being seen on May 10.

Stream flows dropped to nil in June and the creek was dry from July until the end of August; this was the first time Auke Creek has completely stopped flowing. No cutthroat trout were allowed to pass the weir until September 15 when temperatures began to decrease and stream flow increased (Figure 8). A total of 91 cutthroat trout immigrated in 2004, well below the 1997–2003 average of 248 (Table 6). All immigrants were examined for marks and tags (Appendix A2). Of these, 25 were missing their adipose fin and had a PIT tag, and 66 were unmarked. PIT tag retention was thus 100%.

Contrary to the objectives, the unmarked component of immigration was not measured. This oversight occurred during a change in personnel. The length of PIT-tagged immigrants did not vary greatly over time (Figure 10), and averaged 328 mm FL (range 274 to 374 mm FL); the standard deviation of length was 23 mm. The length frequency distribution for both fall and spring migrants showed that few fish meet the 14 inch (356 mm) minimum size limit for harvest in Auke Lake (Figure 11). Because we did not measure unmarked immigrants, length comparisons between tagged fish and the immigrant population as a whole, and between all emigrants and all immigrants in 2004 could not be made.

Marine growth and marine residence of cutthroat trout leaving Auke Creek decreased with increased size of emigrants and later emigration date. Average growth of tagged fish during the period between emigration and immigration was 65 mm (SE = 3.6, range from 39 to 101 mm). The average growth rate during this period was 0.49 mm/day (SE = 0.025). This rate was similar to that observed in the last seven years (Lum and Taylor. 2006a). Marine growth rates tended to decrease (P=0.002) as the size of the emigrating fish increased (Figure 12). The average number of days between emigration and immigration of PIT-tagged cutthroat trout was 132 days (SE = 2.5, range 114 to 152 days), typical of the average hiatuses of 122 to 149 days observed from 1998 to 2003 (Lum et al. 1999-2002; Lum and Taylor 2004; Lum and Taylor. 2006a,b). There was no significant relationship between emigration and immigration dates for cutthroat trout leaving Auke Creek in 2004 (P=0.272 and had a weak r^2 = 0.05) However, there was a significant (P<0.001) and strong (r^2 = 0.95) relationship between emigration date and the hiatus from Auke Lake (Figure 13).

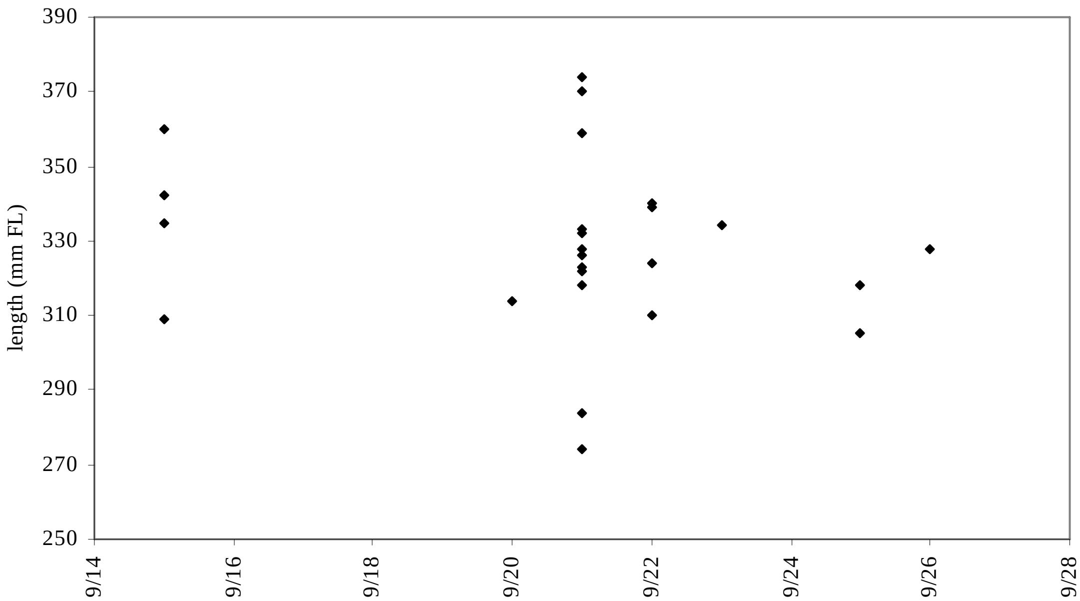


Figure 10.–Lengths of PIT-tagged cutthroat trout returning to Auke Lake during the fall immigration in 2004, by date. Because only returning PIT-tagged immigrants were measured, the sample is not representative of the entire immigrant population and weekly averages were not included here.

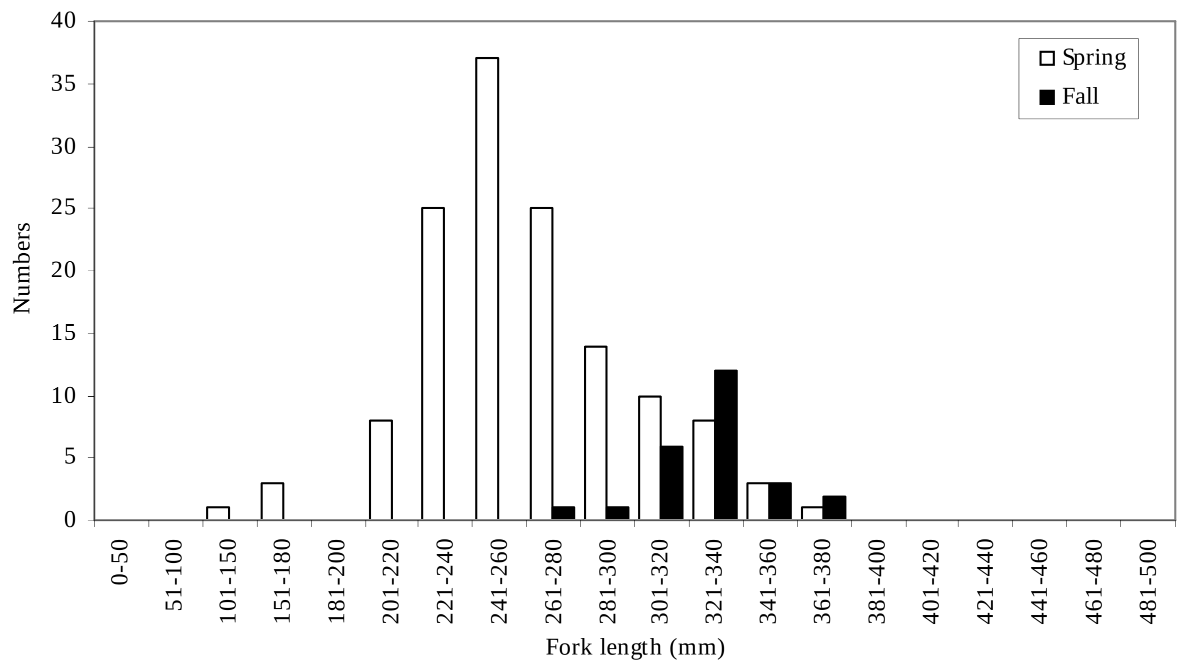


Figure 11.–Lengths of cutthroat trout, pooled by 20 mm groups, during the spring emigration and the fall immigration at the Auke Creek weir in 2004. Because only returning PIT tagged immigrants were measured in the fall, the fall sample is not representative of the entire immigrant population.

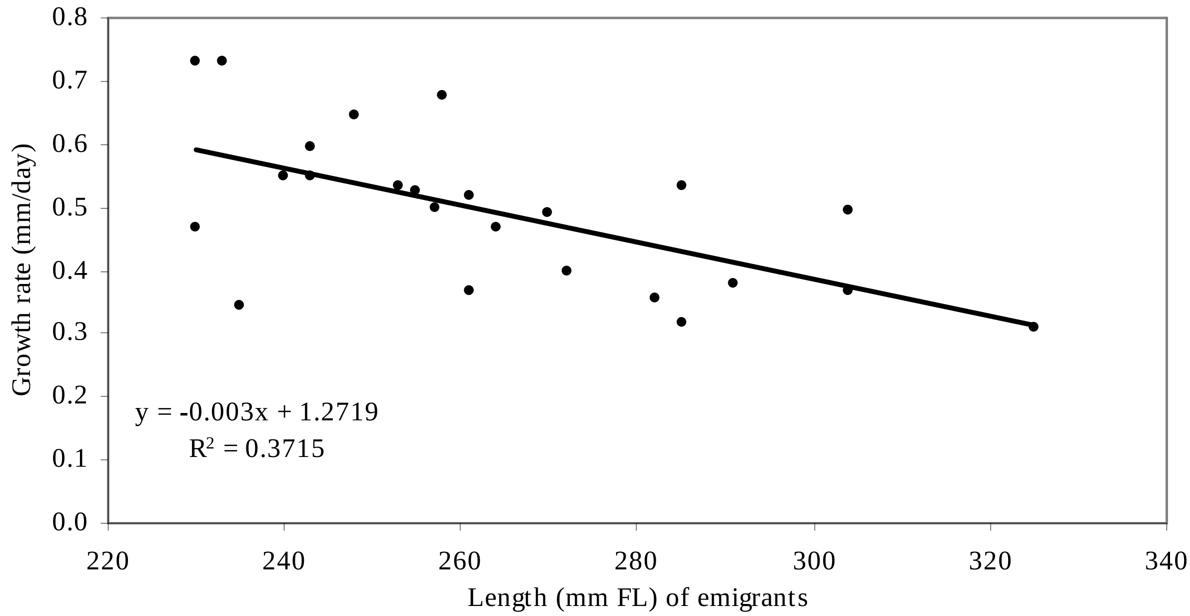


Figure 12.–Marine growth rate (mm /day) of tagged Auke Creek cutthroat trout versus fork length at the time of emigration in 2004.

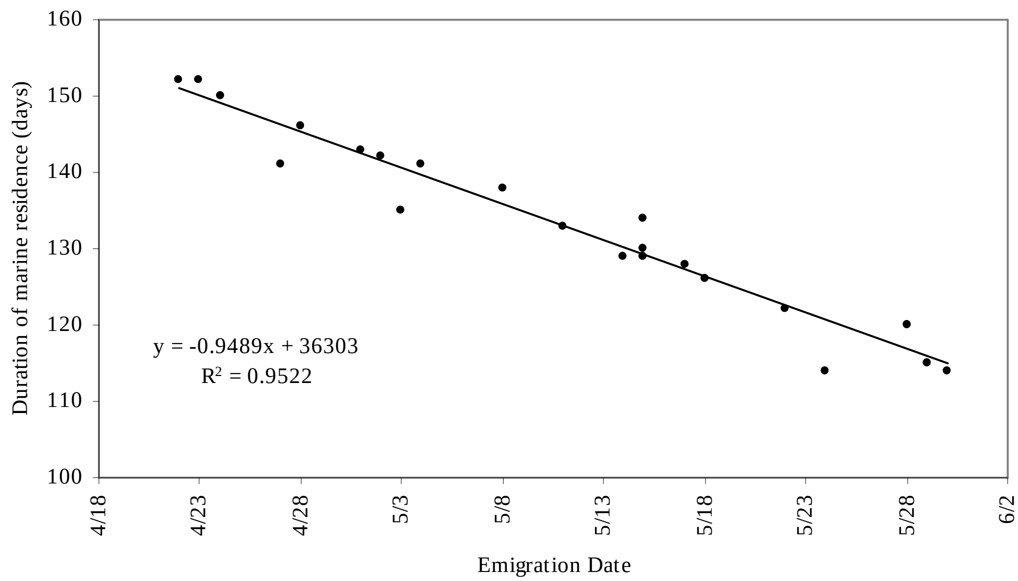


Figure 13.–Relationship between emigration date of tagged cutthroat trout and hiatus from Auke Lake in 2004.

Overwinter survival of anadromous adult cutthroat trout using Auke Lake during the winter of 2003–04 was estimated for the 2003 PIT tagged immigrants. In fall 2003 a total of 29 PIT-tagged cutthroat trout immigrated into Auke Lake (Lum and Taylor. 2006b). Twelve of those fish emigrated from the lake in spring 2004, leaving 17 that either remained in Auke Lake or died over the winter. Three of the 17 fish were caught while sampling in Auke Lake in 2004, and the estimate of overwinter survival estimate of these PIT-tagged fish was 52% (=15/29).

CUTTHROAT TROUT IN AUKE LAKE

Cutthroat trout caught in 2004 in Auke Lake were used in the JS model to estimate the abundance of the population for the previous year. The estimated abundance of cutthroat trout ≥ 180 mm FL in Auke Lake was 414 (SE = 26) in spring 2003. A total of 504 cutthroat trout between 118 and 354 mm FL were captured in Auke Lake from June 7 to June 16, 2004, and only fish ≥ 180 mm were used in the abundance estimate (Table 8). Of the 504 fish, 124 were captured more than once and were considered "redundant" within this sampling event/year. Most unique fish (i.e., non-redundant fish) were in the 201–220 mm FL size class (Figure 14). A total of 290 unique cutthroat trout ≥180 mm FL were captured and released in 2004. Of these, 115 fish had been tagged in previous years and 175 fish had not. Three fish had lost their pit tags (2.7 % of the marked sample). Capture histories and summary statistics for fish ≥180 mm FL sampled since 1998 were compiled for the JS analyses (Appendix A3, Table 9).

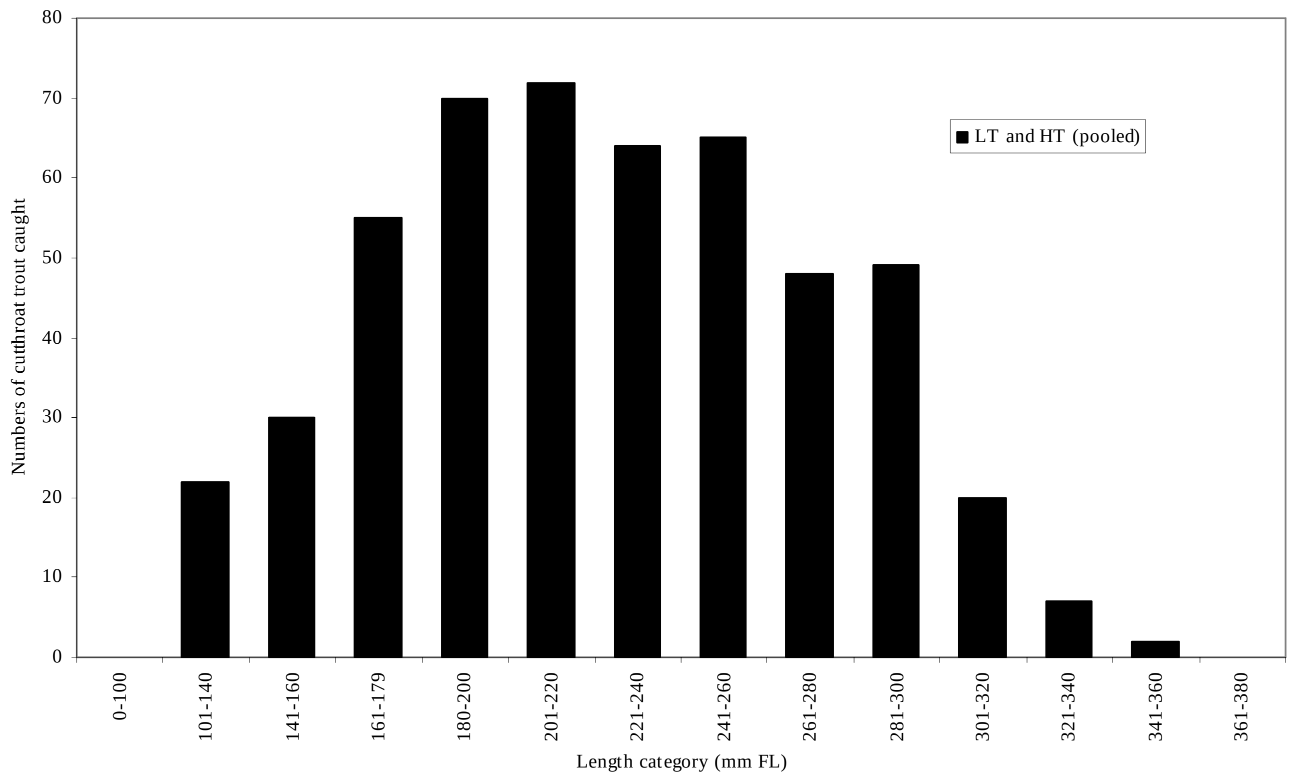


Figure 14.–Fork lengths of cutthroat trout sampled in Auke Lake by gear type in 2004.

Note: Fish captured more than once are not plotted, and no hook and line fishing was conducted in 2004.

Note: These proportions will be expanded to estimate abundance ($\hat{N}_{2004}$) by size in the next annual report when an abundance estimate for 2004 can be calculated. LT = Large traps, and HT = Hoop traps. There was only one hoop trap, so information was pooled after testing for significant differences between catch rates.

Table 8.–Sampling effort (hours), cutthroat trout catch, and catch per unit effort (CPUE, fish per hour) by sampling gear and fish length-class in Auke Lake in 2004.

			≥180 mm		<180 mm		Combined	
Sampling dates	Gear Type	Efforts (hours)	Catch	CPUE	Catch	CPUE	Catch	CPUE
June 7-16	Large traps (15)	3,240	390	0.120	105	0.032	495	0.153
	Hoop traps (1)	216	7	0.032	2	0.009	9	0.042
	All gear	3,456	397	0.115	107	0.031	504	0.146

Note: All captures of a fish are included in the catch. The 2004 trip was a one-event mark and recapture.

Table 9.–Summary statistics for the Jolly-Seber model, Auke Lake, 1998–2004.

Year	n_i	m_i	R_i	r_i	z_i
1998	89	0	89	26	0
1999	352	22	352	96	4
2000	292	94	292	51	6
2001	233	41	233	46	16
2002	259	58	259	98	4
2003	370	99	370	88	3
2004	290	91	290	0	0

n_i = number of fish captured in sample i.
m_i = number of marked fish caught in sample i.
R_i = number fish returned to the population alive with marks from sample i.
r_i = number caught in sample i which are recaptured later.
z_i = number of fish caught before and after sample i , but not caught in sample i.

Marked and unmarked fish mixed completely (P<0.05) between 1999–2003 (Lum and Taylor. 2006b) and 2003–2004. (Appendix A4). Good mixing was expected across years as Auke Lake is relatively small. The component-1, component-2, and overall GOF tests for homogeneous capture/survival probabilities (Table 10, Appendix A5) suggested the JS model does not fit the data well (P<0.05). Inspection of the test results (Table 10) shows the majority (i.e., 3 of 5) of the component-1 GOF statistics were significant (P<0.05). A summary of the capture probabilities from the component-1 GOF test (Robson's test for short-term mortality, Appendix A6) reveals that the probability of recapturing fish in the year that it was tagged was twice that for recapturing fish tagged in previous years. The component-2 GOF tests are less telling (as but 2 of 4 tests are significant at P<0.05) although these are less powerful tests due to small sample sizes (Appendix A5). The poor GOF tests suggest use of the generalized JS model, which estimates separate survival rates for newly captured and previously captured fish (Brownie and Robson. 1983, named "Model 2" in JOLLY and "Analysis 3" in POPAN). Neither the full or generalized model "fit" the data well (P=0.001 for the full JS model and P=0.063 for the generalized "Model 2"). Because the generalized model uses a subset of the available capture histories, precision of those estimates ($\hat{N}_{1999}$=808, SE=428; $\hat{N}_{2000}$=450, SE=83; $\hat{N}_{2001}$=852, SE=321; $\hat{N}_{2002}$=336, SE=45, $\hat{N}_{2003}$=429, SE=38) was much lower than the precision of the estimates from the full JS model (Table 11).

Table 10.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group.

	Component 1		Component 2	
Year	Test statistic	P-value	Test statistic	P-value
1999	3.911	0.048		
2000	4.483	0.034	0.407	0.816*
2001	1.789	0.181	11.246	0.004*
2002	9.344	0.002	0.397	0.820*
2003	3.260	0.071	7.296	0.026*
Overall by component	22.786	< 0.001	19.35	0.013*
Overall	42.13	< 0.001		

Note: Asterisks denote tests that contained a cell with an expected value of less than 2. Overall chi-squares are the sum of the individual test statistics.

Table 11.–Estimates of abundance ($\hat{N}$), survival ($\hat{\phi}$), and births ($\hat{B}$) from the full Jolly-Seber model of cutthroat trout ≥180 mm FL at Auke Lake, 1998–2003.

Year	$\hat{N}$	SE($\hat{N}$)	$\hat{\phi}$	SE($\hat{\phi}$)	$\hat{B}$	SE($\hat{B}$)
1998	-	-	0.411	0.088	-	-
1999	561	118	0.349	0.045	199	69
2000	394	46	0.370	0.071	527	120
2001	672	139	0.218	0.031	155	30
2002	302	25	0.414	0.039	289	23
2003	414	28	-	-	-	-

The 1999 estimate (for example) from the generalized model (808, SE=428) appears to be much larger than the estimates from the full JS (561, SE=118) or Petersen (464, SE=23; Lum et al. 2001) models, but the difference(s) between the estimates from the different models are not statistically significant (P>0.4). The similarity between the estimates from each model is likely the result of high capture rates (35% to 86%).Therefore, the more precise full JS model estimates are preferable, and while there was significant heterogeneity in capture/survival rates by group, the source of the heterogeneity and appropriate corrective procedures (if any) are unknown.

Estimates of abundance, survival, and recruitment of cutthroat trout ≥180 mm FL in Auke Lake are summarized in Table 11. Estimated 2003 harvests at Auke Lake (0 fish, Table 2) and the surrounding marine area (37 fish, Table 3) remain low, although the estimate for Auke Lake is poor (imprecise) because of the low sampling rate (one respondent). Cutthroat trout ≥180 mm FL sampled in Auke Lake in 2003 had an average length of 239 mm FL (SE = 2, range 180 to 354 mm FL). Using the annual abundance estimate (414), 53.8% of the population was ≤240 mm FL (Table 12). The harvest of cutthroat trout in Auke Lake is restricted to fish ≥356 mm FL (14 inches TL), but none of the fish in the sample were harvestable size.

The data from this study has been electronically archived by ADF&G, Research and Technical Services in Anchorage, Alaska (Appendix A7).

DISCUSSION

The Dolly Varden and cutthroat trout assessments in Auke Lake and Auke Creek provide a unique time series of abundance, survival, growth, migration timing, and other life history information. These long-term data sets will become increasingly important as urban development continues in the Juneau area.

TROUT MIGRATIONS

The number of cutthroat trout and Dolly Varden emigrating from Auke Lake annually (Table 6) are highly correlated (r = 86% since 1980 and 93% since 1997). Both emigrations have been declining since the relatively high abundances of the mid-1990s, and they are now at levels seen in the early 1980s. The similarity of the emigration trajectories for each species (Figures 3 and 7) suggests that environmental conditions experienced by both species are largely responsible for the observed changes. Exploitation seems to us an unlikely factor for these trends because the harvest rates for each species appear to be low (Tables 2 and 3), assuming that all harvests are fully reported. Similarly, immigration rates for both species since 1997 (Table 6) are well correlated (r = 90%), though the cutthroat immigration (range 467 in 1997 to 91 in 2004) has declined at twice the rate of that for Dolly Varden (range 5,705 in 1997 to 2,564 in 2004).

Trends in the average length of cutthroat trout and Dolly Varden emigrating annually from Auke Lake are also similar, though some data points are not highly correlated (r = 54% since 1982, Figure 15). Length frequency plots for Dolly Varden emigrants across years (1970, 1980–85, and 1987–2004) show how size-related cohorts (or age class) moved through the population, and that overall, the length distribution is relatively stable over time relative to the long-term average (Appendix 8 and 9). Similar plots for cutthroat trout emigrants across years (1982–2004) also show strong size-related cohorts (or age class) moving through the

Table 12.–Length composition and estimated abundance at length for cutthroat trout ≥180 mm FL in Auke Lake in 2003.

Length k, mm FL	n_k	$\hat{p}_k$	$S\hat{E}(\hat{p}_k)$	$\hat{N}_k$	$S\hat{E}(\hat{N}_k)$
180–200	70	0.189	0.007	78.3	6.0
201–220	55	0.149	0.006	61.5	4.9
221–240	74	0.200	0.007	82.8	6.3
241–260	63	0.170	0.006	70.5	5.4
261–280	50	0.135	0.006	55.9	4.5
281–300	39	0.105	0.005	43.6	3.7
301–320	13	0.035	0.003	14.5	1.6
321–340	4	0.011	0.002	4.5	0.8
341–360	2	0.005	0.001	2.2	0.5
361–380	0	0.000	0.000	0.0	0.0
Total	370			$\hat{N}$ = 414	

Note: Number sampled (nk), proportion ($\hat{p}_k$), abundance ($\hat{N}_k$), and standard error ($S\hat{E}$) are shown for each 20-mm length class (Lum and Taylor 2006a). Fish captured more than once were not used to calculate proportions (Lum and Taylor 2006a).

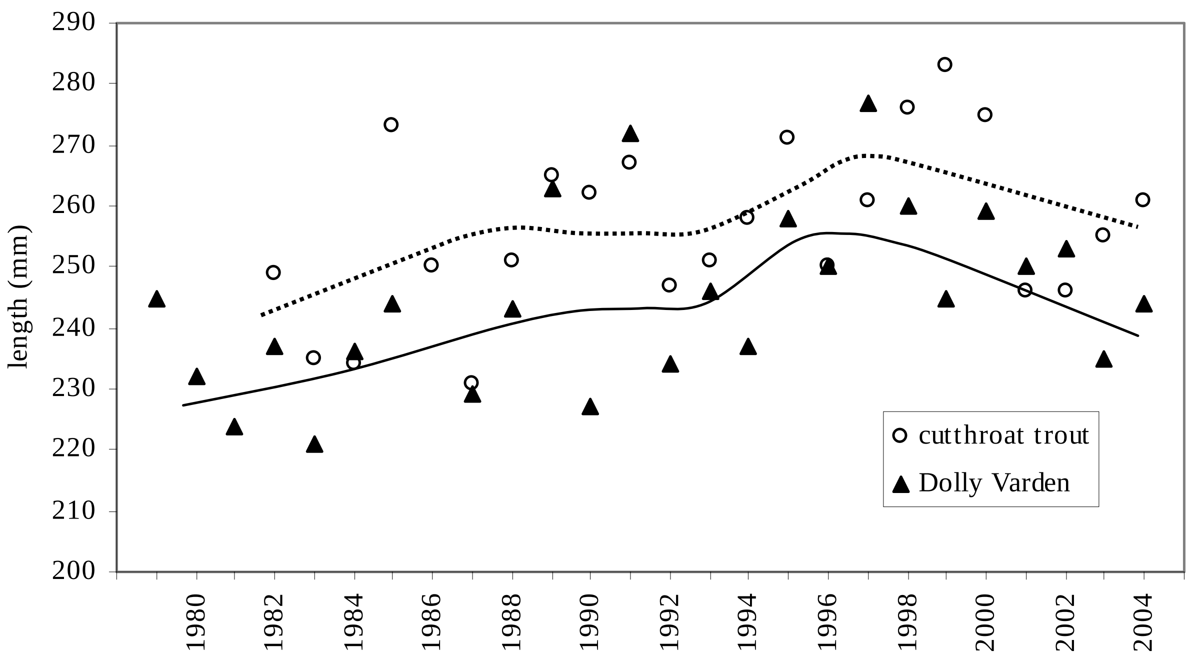


Figure 15.–Average fork length of cutthroat trout (1982–2004) and Dolly Varden (1970 and 1980–2004) emigrants at Auke Creek.

Note: The cutthroat trout is represented by open circles and dashed line and Dolly Varden with solid triangles and smooth line. The line represents the trend over all years as depicted by local regression.

population and a long-term stability in the size-composition over time (Appendix 10 and 11).

Not surprisingly, environmental conditions mediate annual emigration dates for both species in Auke Lake. Simple linear regression (SLR) shows that ice-out date at Auke Lake (B. Wing, NOAA-NMFS, personal communication) is a significant predictor (P < 0.01) of the date the emigrations are 50% (Table 6), 25%, 10%, and 5% completed for each species. Annual variation of the migration dates probably results from a complex interaction among variables such as seasonal water temperatures, stream flows, light levels, food supplies, photoperiod, and life stage or age of the population. While ice-out dates are largely a product of spring conditions, they explain (based on r^2) about 50% of the variation in dates that 50% and 25% of the Dolly Varden emigrations are completed and about 45% of the variation in dates that 10% and 5% of the cutthroat trout emigrations are completed. SLR also shows that year (1980–2004) is a significant (P < 0.05) but weak (r^2 < 0.5) predictor of the 50%, 25%, 10%, and 5% emigration dates for cutthroat trout on Auke Lake. For Dolly Varden, SLR relates year with dates that emigrations are 50%, 25%, 10%, and 5% complete at, respectively, the 0.22, 0.02, 0.20, and 0.15 levels of significance. The migration dates for both species are getting earlier over time. Two "survival" statistics were computed for migrant populations in 2004: the rate that spring emigrants return to Auke Lake in the fall (18.7%), and the rate that fall immigrants (in 2003) leave Auke Lake in the spring of 2004 (52%). The "ocean survival" statistic does not track emigrants that survive their ocean migration but do not (at least immediately) return to Auke Lake. There is very little information on this life history possibility, but note (see discussion below) that a few fish tagged in Auke Lake or Auke Creek have been found in other systems, and a few tagged emigrants have returned to overwinter in Auke Lake after a year or more at large.

The "overwinter" survival statistic noted above does not track immigrants that survive the winter but elect to spend a summer (or longer) in Auke Lake instead of emigrating in the spring. This life history has also been observed (Lum et al. 2000-2002; Lum and Taylor. 2006a,b), but it is also a rare occurrence. The overwinter survival rate of 52% is similar to the rates we have estimated in the past: 67% in 1997–98, 58% in 1998–99, 60% in 1999–2000, 74% in 2000–2001, 48% in 2001–2002, and 65% 2002–2003 (Lum et al. 1999-2002; Lum and Taylor 2004, 2006a,b), yielding an average survival rate of 62%.

CUTTHROAT TROUT IN AUKE LAKE

Auke Lake is home to both resident and sea-run cutthroat trout. There are indications that some sea-run trout spawn in Auke Lake (Lum et al. 2001) in the spring after overwintering in Auke Lake. Their progeny reside (rear) in the lake and/or tributaries prior to their spawning migrations within or outside the Auke Lake system. This suggests that heterogeneity in capture and survival probabilities based on life history (resident and anadromous) trajectories is possible in this experiment.

Indeed, heterogeneity based on capture history has been observed in all previous JS analyses at Auke Lake (fish caught for the first time in year *i* have been *more* likely to be recaptured in year *i* than fish tagged in previous years). The presence of anadromous trout and perhaps age dependent mortality are thought to be the likely reasons for this heterogeneity (Lum and Taylor 2004). The heterogeneity imparts some bias to our estimates. Assuming, for illustration, that estimates from generalized (in POPAN) JS models for 2000–2003 are unbiased, our JS estimates for this period (Table 11) would be biased low by about 11% (or 5% in 2003). The JS survival estimates should suffer less from the heterogeneity (Pollock et al. 1990); they may be biased low by 5% using the comparison above (or about 1% in 2002).

Although there is no confidence in applying the generalized JS model to these data, one apparent conclusion from the study is that fish first captured *prior* to the most recent sampling event "survive" at a lower (almost one-half) rate than newly captured fish; our average annual survival rate, 1998–2002, for all fish is 0.35 (Table 11), while the average rates for new and previously captured fish (from the generalized Model 2 in JOLLY) are 0.51 and 0.21 respectively. The relatively poor average "survival" of the older capture group may result from permanent emigration of trout (immature anadromous fish in Auke Lake that emigrate and do not return) and/or age dependant mortality.

The average “survival” rate estimate for newly captured fish (0.51) in Auke Lake is similar to estimates made for populations of resident / lake-bound fish in Southeast Alaska (Neck Lake - 51%, SE = 6%, Harding et al. 1999; Florence Lake - 40%, SE = 2% and 52%, SE = 3%; Rosenkranz et al. 1999). Interestingly, a JS analysis of Auke Lake capture history data for 1998–2001 (Lum and Taylor 2004), which excluded all fish observed at the weir, yielded an annual survival estimate of 51% (SE = 6.5%) which is similar to the average for newly captured fish in Auke Lake, and as noted above, for some resident populations in Southeast Alaska.

Tagging of the emigrating trout and char migrants at Auke Creek has complimented other local projects where tagged migrants are sampled and movement between systems can be determined. An example of this is the recent work at Jordan Creek, and Duck Creek (Lum and Glynn, *in prep)*, and at Dredge Creek (*unpublished data*). A few (<5%) PIT-tagged cutthroat trout that leave Auke Lake immigrate into these systems, overwinter for up to two years, and then emigrate in the spring. Additional studies along the Juneau roadside, supported by the emigrant tagging at Auke Lake, would help us better determine the importance of these migratory populations to the Juneau roadside fisheries.

ACKNOWLEDGMENTS

We would like to thank Mark Schwan for help with the operational plan, and John Der Hovanisian for his review on this report. The authors would like to thank Bob Marshall for his help preparing the operational plan, assisting in the analysis, and reviewing the report. We also thank John Burr for his helpful review of the report. Kurt Kondzela helped with the installation of the weir, fish counting, and lake sampling. We would also like to thank Rocky Holmes, Mark Schwan, John Der Hovanisian, and Dave Love for their help sampling at the weir and lake.

REFERENCES CITED

Armstrong, R. H., and J. E. Morrow. 1980. The Dolly Varden charr, *Salvelinus malma* [*In*] E. K. Balon, editor. "Charrs: Salmonid fishes of the *Genus Salvelinus*". D. W. Junk Publishers, the Hague, Netherlands.

Arnason, A. N., C. J. Schwarz, and G. Boyer. 1998. POPAN-5: A data maintenance and analysis system for mark-recapture data. Scientific Report, Department of Computer Science, University of Manitoba, Winnipeg. viii+319 pp.

Behnke, R. J. 1979. Management and utilization of native trouts. Monograph of the native trouts of the *Genus Salmo* of western North America. Joint publication of USFS, USFWS, and BLM.

Brown, C. D. J., and J. E. Bailey. 1949. Time and pattern of scale formation in Yellowstone trout *Salmo clarkii lewisii*. Paper No. 234 for Project No. MS844. Montana State College, Agricultural Experimental Station Journal Series, Bozeman, MT.

Brownie, C., and D. S. Robson. 1983. Estimation of time-specific survival rates from tag-resighting samples: a generalization of the Jolly-Seber model. Biometrics 39:437-453.

Ericksen, R. P. 1999. Scale aging manual for coastal cutthroat trout from Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 99-4, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/sp99-04.pdf

Harding, R. D., R. E. Chadwick, and G. M. Freeman. 1999. Abundance, length composition, and annual mortality of cutthroat trout at Neck Lake, Southeast Alaska, 1996 through 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-42. Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-42.pdf

Laakso, M., and O. B. Cope. 1956. Age determination in Yellowstone cutthroat trout by the scale method. Journal of Wildlife Management 20(2):138-153.

Lum, J. L., and B. J. Glynn. *In prep*. Smolt production, adult harvest, and escapement of coho salmon from Jordan and Ducks Creeks, Southeast Alaska, 2002-2003. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

REFERENCES CITED (Continued)

Lum, J. L., J. D. Jones, K. Kondzela, and S. G. Taylor. 1999. Dolly Varden and cutthroat trout populations in Auke Lake, Southeast Alaska, during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-32, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds99-32.pdf

Lum, J. L., J. D. Jones, K. Kondzela, and S. G. Taylor. 2000. Dolly Varden and cutthroat trout populations in Auke Lake, Southeast Alaska, during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-30, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds00-30.pdf

Lum, J. L., J. D. Jones, and S. G. Taylor. 2001. Dolly Varden and cutthroat trout populations in Auke Lake, Southeast Alaska, during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 01-33, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds01-33.pdf

Lum, J. L., J. D. Jones, and S. G. Taylor. 2002. Dolly Varden and Cutthroat Trout migrations at Auke Creek in 2001, and abundance of Cutthroat Trout in Auke Lake Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 02-21, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds02-21.pdf

Lum, J. L., K. Kondzela, J. D. Jones, and S. G. Taylor. 1998. Dolly Varden char and sea-run cutthroat trout populations at Auke Lake, Southeast Alaska, during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-43, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds98-43.pdf

Lum, J. L., and S. G. Taylor. 2004. Dolly Varden and cutthroat trout migrations at Auke Creek in 2002, and abundance of cutthroat trout in Auke Lake, Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 04-12, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds04-12.pdf

Lum, J. L., and S. G. Taylor. 2006a. Abundance of cutthroat trout in Auke Lake, Southeast Alaska, in 2004. Alaska Department of Fish and Game, Fishery Data Series No. 06-21, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-21.pdf

Lum, J. L., and S. G. Taylor. 2006b. Dolly Varden and cutthroat trout migrations at Auke Creek in 2003, and abundance of cutthroat trout in Auke Lake, Southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 06-09, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-09.pdf

Neimark, L. M. 1984a. Enhancement of the recreational fishing opportunities in the Juneau area. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (G-III-A), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-16(25)G-III-A.pdf

Neimark, L. M. 1984b. Fish migration studies in Southeast Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (G-II-D), Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/f-9-16(25)G-II-D.pdf

Northcote, T. G. 1997. Why sea-run? An exploration into the migratory/residency spectrum of coastal cutthroat trout. [*In*] J. D. Hall, P. A. Bisson and R. E. Gresswell editors. Sea-run cutthroat trout: biology, management, and future conservation. American Fisheries Society, Corvallis.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for mark-recapture experiments. Wildlife Monograph 107.

Robson, D. S. 1969. Mark-recapture methods of population estimation. Pages 120-140 [in] N. L. Johnson and H. Smith, Jr., editors, New developments in survey sampling. John Wiley and Sons, New York.

Rosenkranz, G., R., P. Marshall, R. D. Harding, and D. R. Bernard. 1999. Estimating natural mortality and abundance of potamodromous lake dwelling cutthroat trout at Florence Lake, Alaska. Alaska Department of Fish and Game, Fishery Manuscript No. 99-1, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fm99-01.pdf

Schwan, M. 1990. Strategic plans for the Juneau, Ketchikan, and Sitka recreational fisheries. Alaska Department of Fish and Game, Juneau.

REFERENCES CITED (Continued)

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

Spense, C. R. 1990. Management options for sea-run cutthroat trout on the Queen Charlotte Islands. Province of British Columbia Ministry of Environment Fish and Wildlife Branch Report.

Taylor, S. G., and J. L. Lum. *Unpublished-a*. Annual report Auke Creek weir 1998, operations, fish counts, and historical summaries. 1999. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-b*. Annual report Auke Creek weir 1999, operations, fish counts, and historical summaries. 2000. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-c*. Annual report Auke Creek weir 2000, operations, fish counts, and historical summaries. 2001. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-d*. Auke Creek weir 2001 Annual Report, operations, fish counts, and historical summaries. 2002. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-e*. Auke Creek weir 2002 Annual Report, operations, fish counts, and historical summaries. 2003. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-f*. Auke Creek weir 2003 Annual Report, operations, fish counts, and historical summaries. 2004. National Marine Fisheries Service. Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Taylor, S. G., and J. L. Lum. *Unpublished-g*. Auke Creek weir 2004 Annual Report, operations, fish counts, and historical summaries. 2005. National Marine Fisheries Service. Auke Bay Laboratory,11305 Glacier Highway, Juneau, Alaska.

Trotter, P. C. 1997. Sea-run cutthroat trout: life history profile. [*In*] J. D. Hall, P. A. Bisson and R. E. Gresswell editors. Sea-run cutthroat trout: biology, management, and future conservation. American Fisheries Society, Corvallis.

Wright, S. 1992. Guidelines for selecting regulations to manage open-access fisheries for natural populations of anadromous and resident trout in stream habitats. North American Journal of Fisheries Management 12:517-527.

APPENDIX A

Appendix A1.–Daily water temperature and number of spring emigrants at Auke Creek weir in 2004.

	Water temperature	Pink Salmon fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead
March 1	2.0							
2	2.1							
3	2.1	114	0	0	7	0	0	0
4	2.1	174	0	0	10	0	0	0
5	2.0	248	0	0	15	0	0	0
6	1.9	165	0	0	12	0	0	0
7	2.0	289	0	0	44	0	0	0
8	2.1	263	0	0	34	0	0	0
9	2.1	226	0	0	22	0	0	0
10	2.1	345	0	0	39	0	0	0
11	2.1	325	0	0	23	0	0	0
12	2.3	390	0	0	50	0	0	0
13	2.3	360	0	0	47	0	0	0
14	2.3	403	0	0	35	0	0	0
15	2.4	451	0	0	33	0	0	0
16	2.3	330	0	0	30	0	0	0
17	2.4	611	0	0	42	0	0	0
18	2.5	512	0	0	38	0	0	0
19	2.5	619	0	0	23	0	0	0
20	2.6	889	0	0	27	0	1	0
21	2.6	700	0	0	31	0	0	0
22	2.6	599	0	0	44	0	0	0
23	2.6	916	0	0	41	1	0	0
24	2.9	702	0	0	41	0	0	0
25	2.9	867	0	0	20	0	0	0
26	3.1	2,079	0	0	34	0	0	0
27	3.1	2,168	0	0	38	1	0	0
28	3.2	2,234	0	0	32	2	0	0
29	3.0	2,313	0	0	37	0	0	0
30	3.0	1,383	0	0	20	1	0	0
31	3.1	2,275	0	0	35	1	0	0
April 1	3.2	2,157	0	0	27	0	1	0
2	3.1	3,305	0	0	36	0	0	0
3	3.1	8,588	0	0	44	1	0	0
4	3.0	9,421	0	0	45	22	0	0
5	3.2	3,541	0	0	20	9	0	0
6	3.4	5,451	0	0	21	12	0	0
7	3.3	3,454	0	0	18	2	0	0
8	3.7	2,532	0	0	7	14	0	0
9	3.7	4,998	0	0	19	4	0	0
10	3.9	5,655	0	0	13	7	3	0
11	4.2	8,969	0	0	37	1	0	0
12	4.7	8,675	0	0	21	23	0	0
13	4.9	7,492	0	0	25	14	1	0
14	5.4	9,815	0	0	17	10	0	0
15	4.9	10,017	0	0	27	27	1	0
16	4.7	5,054	0	0	13	16	0	0
17	4.9	4,742	0	0	17	11	0	0
18	5.1	6,422	0	0	16	6	0	0
19	5.2	4,946	0	0	8	6	0	0

-continued-

Appendix A1.–Page 2 of 3.

	Water temperature	Pink Salmon fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead
April 20	5.7	5,521	0	0	5	9	0	0
21	6.2	5,793	0	0	9	11	2	0
22	6.5	3,739	0	0	0	21	4	0
23	6.3	4,917	0	1	2	18	4	0
24	6.2	3,680	0	0	2	18	3	0
25	6.2	1,653	0	1	2	9	4	0
26	6.0	2,771	0	0	1	44	2	0
27	6.4	926	1	3	1	423	5	0
28	7.2	1,195	1	0	7	47	2	0
29	7.2	508	0	2	5	132	2	0
30	8.5	400	1	3	5	262	2	0
May 1	9.7	122	1	8	2	347	4	0
2	9.3	52	0	12	5	90	3	0
3	9.6	25	2	9	0	209	5	0
4	10.9	19	1	21	3	512	6	0
5	10.0	17	10	42	3	216	3	0
6	10.7	18	9	19	1	247	1	0
7	11.3	13	6	3	0	217	1	0
8	11.6	6	16	67	2	240	4	0
9	12.0	1	63	67	1	66	1	0
10	12.1	2	143	237	4	101	5	0
11	12.2	3	314	931	1	235	5	1
12	12.7	0	365	1,849	1	69	1	0
13	13.5	0	453	3,605	0	74	6	0
14	14.2	1	336	2,688	3	36	2	0
15	14.3	1	371	2,693	1	24	9	0
16	14.9	0	247	2,296	0	13	2	0
17	14.6	1	298	1,329	0	3	1	0
18	14.6	0	181	1,004	0	10	2	1
19	14.6	0	210	1,258	1	7	2	0
20	15.1	0	121	951	0	4	3	0
21	16.1	0	163	863	0	2	1	0
22	15.9	0	150	487	0	1	5	0
23	16.1	0	96	186	3	0	3	0
24	16.4	0	92	155	0	5	3	0
25	15.7	0	59	68	1	4	6	1
26	15.0	0	39	32	0	2	1	0
27	14.9	0	135	26	1	9	2	0
28	14.9	0	108	39	10	6	2	0
29	15.0	0	72	21	1	3	4	0
30	14.7	0	89	10	1	5	1	0
31	14.8	0	63	13	0	0	2	0
June 1	14.5	0	29	15	3	3	0	1
2	14.5	0	26	28	1	3	1	0
3	14.2	0	73	8	0	2	0	0
4	15.0	0	45	8	2	1	0	0
5	15.3	0	35	5	0	2	1	0
6	15.2	0	9	7	0	1	0	0

-continued-

Appendix A1.–Page 3 of 3.

	Water temperature	Pink Salmon fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead
June 7	15.7	0	48	5	0	1	0	0
8	16.1	0	22	4	0	0	0	0
9	15.5	0	15	4	0	0	0	0
10	15.2	0	8	4	0	0	1	0
11	15.2	0	17	4	0	0	0	0
12	15.2	0	8	0	0	0	0	0
13	15.6	0	10	4	0	0	0	0
14	15.1	0	4	0	0	0	0	0
15	15.0	0	5	3	0	0	0	0
16	14.8	0	3	2	0	0	0	0
17	15.5	0	0	1	0	0	0	0
18	16.3	0	5	3	0	0	0	0
19	18.0	0	2	1	0	0	0	0
20	18.7	0	1	1	0	0	0	0
21	18.8	0	0	0	0	0	0	0
22	19.4	0	0	0	0	0	0	0
23	19.6	0	0	0	0	0	0	0
24	20.0	0	0	0	0	0	0	0
25	20.2	0	0	0	0	0	0	0
26	19.8	0	0	0	0	0	0	0
27	18.6	0	0	0	0	0	0	0
28	17.8	0	0	0	0	0	0	0
29	17.7	0	0	0	0	0	0	0
30	17.8	0	0	0	0	0	0	0
Totals		169,568	4,581	21,106	1,425	3,955	136	4

Appendix A2.–Daily water temperatures and number of fall immigrants at Auke Creek weir in 2004. Counts do not include sockeye or coho jacks (0-ocean; < 400 mm MEF).

	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead
July 1	17.0	0	0	0	0	0	0	0	0
2	17.0	0	0	0	0	0	0	0	0
3	16.8	0	0	0	0	0	0	0	0
4	16.8	0	0	0	0	0	0	0	0
5	16.9	0	0	0	0	0	0	0	0
6	16.4	0	0	0	0	0	0	0	0
7	16.4	0	0	0	0	0	0	0	0
8	16.4	0	0	0	0	0	0	0	0
9	16.2	0	0	0	0	0	0	0	0
10	15.2	0	0	0	0	0	0	0	0
11	14.8	0	0	0	0	0	0	0	0
12	14.8	0	0	0	0	0	0	0	0
13	15.2	0	0	0	0	0	0	0	0
14	15.6	0	0	0	0	0	0	0	0
15	15.2	0	0	0	0	0	0	0	0
16	15.2	0	0	0	0	0	0	0	0
17	15.2	0	0	0	0	0	0	0	0
18	14.4	0	0	0	0	0	0	0	0
19	13.6	0	0	0	0	0	0	0	0
20	14.4	0	0	0	0	0	0	0	0
21	14.4	0	0	0	0	0	0	0	0
22	14.8	0	0	0	0	0	0	0	0
23	15.6	0	0	0	0	0	0	0	0
24	15.6	0	0	0	0	0	0	0	0
25	16.2	0	0	0	0	0	0	0	0
26	16.6	0	0	0	0	0	0	0	0
27	16.2	0	0	0	0	0	0	0	0
28	17.4	2,454	12	466	0	1	115	0	0
29	17.0	231	11	944	0	1	307	0	0
30	17.8	68	9	759	0	0	86	0	0
31	17.0	8	4	53	0	0	1	0	0
Aug. 1	16.6	4	0	117	0	0	0	0	0
2	16.6	17	13	605	0	2	227	0	0
3	17.0	2	0	107	0	0	66	0	0
4	17.8	6	3	60	0	0	67	0	0
5	17.8	6	0	53	0	0	39	0	1
6	17.8	0	0	21	0	0	38	0	0
7	17.7	6	1	8	0	0	22	0	0
8	18.2	0	0	2	0	0	24	0	0
9	18.6	0	0	0	0	0	12	0	0
10	19.3	0	0	0	0	0	14	0	0
11	19.3	0	0	0	0	0	5	0	0
12	18.6	1	0	0	0	0	5	0	0
13	18.2	10	1	1	0	0	10	0	0

-continued-

	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead
Aug. 14	18.6	0	0	0	0	0	3	0	0
15	19.3	1	0	0	0	0	1	0	0
16	19.7	0	0	0	0	0	0	0	0
17	19.7	0	0	0	0	0	2	0	0
18	19.7	0	0	0	0	0	0	0	0
19	19.0	0	0	0	0	0	0	0	0
20	18.6	0	0	0	0	0	0	0	0
21	17.8	0	0	0	0	0	0	0	0
22	17.8	0	0	0	0	0	0	0	0
23	17.4	0	0	0	0	0	0	0	0
24	17.0	0	0	0	0	0	0	0	0
25	17.0	1	12	0	0	0	2	0	0
26	16.6	0	0	0	0	0	0	0	0
27	16.6	9	447	2	0	0	1	0	0
28	16.6	15	496	2	0	1	0	0	0
29	16.2	21	517	2	0	1	5	0	0
30	16.2	9	438	5	0	6	22	0	0
31	16.0	0	270	0	0	6	4	0	0
Sept. 1	16.0	2	133	0	0	2	4	0	0
2	16.2	0	178	0	0	2	2	0	0
3	15.6	30	1,500	2	0	6	31	0	0
4	15.2	31	1,270	1	1	7	41	0	0
5	14.8	7	342	0	0	5	17	0	0
6	14.4	2	386	0	0	4	67	0	0
7	13.6	1	206	0	0	0	33	0	0
8	13.6	1	85	0	0	0	23	0	0
9	13.2	0	53	0	0	2	71	0	0
10	13.2	1	44	0	0	0	47	0	0
11	13.2	0	39	0	0	0	13	0	0
12	12.9	0	69	0	0	0	12	0	0
13	12.5	0	74	1	0	0	15	0	0
14	12.5	8	53	0	63	0	71	0	0
15	12.5	2	83	0	41	0	110	10	0
16	12.1	2	24	0	19	0	72	0	0
17	12.1	0	11	0	37	0	120	0	0
18	11.7	0	6	0	3	0	152	0	0
19	11.7	0	6	0	10	0	68	0	0
20	11.7	0	2	0	1	0	18	5	0
21	11.3	0	4	0	71	0	129	19	0
22	11.3	2	0	0	36	0	49	14	0
23	10.5	0	0	0	27	0	29	9	1
24	10.5	0	0	0	10	0	41	3	0
25	10.5	0	0	0	28	0	133	8	0
26	10.5	0	0	0	17	0	17	2	0
27	10.1	0	0	0	7	0	11	2	0
28	9.8	0	0	0	6	0	13	1	0
29	9.8	0	0	0		0	10	1	0
30	9.8	0	0	0	3	0	5	1	0

-continued-

Appendix A2.–Page 3 of 3.

	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead
Oct. 1	9.8	0	0	0	2	0	5	2	0
2	9.8	0	0	0	3	0	5	0	0
3	9.8	0	0	0	2	0	9	3	0
4	9.8	0	0	0	5	0	7	1	0
5	9.8	0	0	0	0	0	3	0	0
6	9.8	0	0	0	0	0	2	1	0
7	9.4	0	0	0	0	0	1	2	0
8	9.4	0	0	0	0	0	0	0	0
9	9.4	0	0	0	6	0	8	2	0
10	9.4	0	0	0	2	0	2	1	0
11	9.4	0	0	0	1	0	2	1	0
12	9.0	0	0	0	1	0	6	0	0
13	9.0	0	0	0	8	0	1	0	0
14	9.4	0	0	0	4	0	3	0	0
15	9.4	0	0	0	2	0	0	0	0
16	9.0	0	0	0	0	0	2	1	0
17	8.6	0	0	0	0	0	1	0	0
18	8.0	0	0	0	0	0	2	1	0
19	7.4	0	0	0	0	0	0	0	0
20	7.0	0	0	0	0	0	0	0	0
21	7.0	0	0	0	0	0	0	0	0
22	6.6	0	0	0	0	0	0	0	0
23	6.2	0	0	0	0	0	1	1	0
24	6.2	0	0	0	0	0	1	0	0
25	6.2	0	0	0	0	0	1	0	0
26	5.8	0	0	0	0	0	0	0	0
27	5.8	0	0	0	0	0	0	0	0
28	5.8	0	0	0	0	0	0	0	0
29	5.8	0	0	0	0	0	0	0	0
30	5.8	0	0	0	0	0	0	0	0
31	5.8	0	0	0	0	0	0	0	0
Total		2,958	6,802	3,211	416	46	2,564	91	2

Appendix A3.–Capture histories for the Auke Lake Jolly-Seber model, 1998–2004.

Capture history[a]	Frequency	Capture history[a]	Frequency	Capture history[a]	Frequency
1110000	2	0101000	4	0001010	2
1100000	20	0100100	2	0001001	1
1010000	4	0100000	236	0001000	151
1000000	63	0011110	1	0000111	16
0111100	2	0011100	2	0000110	68
0111000	1	0011000	31	0000101	2
0110111	1	0010100	7	0000100	115
0110100	5	0010000	157	0000011	71
0110010	1	0001110	10	0000010	200
0110000	78	0001100	28	0000001	199

[a] A "0" signifies not captured during that particular sampling event while a "1" signifies a capture; e.g., a capture history of 1,1,1,0 represents a group of fish that were captured during the 1st, 2nd, and 3rd sampling events and not captured during the 4th event. The sampling events correspond to years: 1998, 1999, 2000, etc.

Appendix A4.–Number of cutthroat trout marked in 2003 and recaptured in 2004 by stratum, and chi-square tests for mixing between years.

Stratum fish was marked	Total fish marked in 2003	Numbers recaptured in 2004 by stratum				Number not seen	Proportion recaptured
		A[a]	B[b]	C[c]	Total (all strata)		
A	91	8	4	3	15	76	0.16
B	135	4	12	3	19	116	0.14
C	144	4	3	14	21	123	0.15
Total	370	16	19	20	55	315	0.15
Unmarked fish caught		68	83	84	235		
Total caught in recapture event		84	102	104	290		
Marked fraction		0.19	0.19	0.19	0.19		

X^2 = 0.01, 2 df, P = 0.99, *Accept H_o: marked fraction is constant across recovery strata*

[a] Study areas 1, 2, and 3.

[b] Study areas 4, 5, and 6.

[c] Study areas 7 and 8.

Appendix A5.–Breakdown of statistics for homogeneous capture/survival probabilities by tag group for the Jolly-Seber experiment at Auke Lake. $\hat{p} \rightarrow$ is the probability of capture for each group.

Component 1 test for 1999		First captured in 1998	First captured in 1999
Captured in 1999 and recaptured in 2000		2.00	94.00
Captured in 1999 and not recaptured in 2000		20.00	236.00
χ^2 = 3.911, 1 df, P = 0.048	$\hat{p} \rightarrow$	0.091	0.285

Component 1 test for 2000		First captured in 1999	First captured in 2000
Captured in 2000 and recaptured in 2001		10.00	41.00
Captured in 2000 and not recaptured in 2001		84.00	157.00
χ^2 = 4.483, 1 df, P = 0.034	$\hat{p} \rightarrow$	0.106	0.207

Component 2 test for 2000		Captured in 1998, not in 1999	Captured in 1998 and 1999	First captured in 1999
Captured in 2000		4.00	2.00	88.00
Captured in 2001, not in 2000		0.00	0.00	6.00
χ^2 = 0.407, 2 df, P = 0.816	$\hat{p} \rightarrow$	1.00	1.00	0.936

Component 1 test for 2001		First captured in 2000	First captured in 2001
Captured in 2001 and recaptured in 2002		5.00	41.00
Captured in 2001 and not recaptured in 2002		36.00	151.00
χ^2 = 1.789, 1 df, P = 0.181	$\hat{p} \rightarrow$	0.122	0.214

Component 2 test for 2001		Captured in 1999, not in 2000	Captured in 1999 and 2000	First captured in 2000
Captured in 2001		4.00	3.00	34.00
Captured in 2002, not in 2001		2.00	7.00	7.00
χ^2 = 11.246, 2 df, P = 0.004	$\hat{p} \rightarrow$	0.667	0.300	0.829

Component 1 test for 2002		First captured in 2001	First captured in 2002
Captured in 2002 and recaptured in 2003		12.00	86.00
Captured in 2002 and not recaptured in 2003		46.00	115.00
χ^2 = 9.344, 1 df, P = 0.002	$\hat{p} \rightarrow$	0.207	0.428

Component 2 test for 2002		Captured in 2000, not in 2001	Captured in 2000 and 2001	First captured in 2001
Captured in 2002		15.00	5.00	38.00
Captured in 2003, not in 2002		1.00	0.00	3.00
χ^2 = 0.397, 2 df, P = 0.820	$\hat{p} \rightarrow$	0.938	1.00	0.927

-continued-

Appendix A5.–Page 2 of 2.

Component 1 test for 2003		First captured in 2002	First captured in 2003
Captured in 2003 and recaptured in 2004		17.00	71.00
Captured in 2003 and not recaptured in 2004		82.00	200.00
χ^2 = 3.260, 1 df, P = 0.071	$\hat{p} \rightarrow$	0.172	0.262

Component 2 test for 2003		Captured in 2001, not in 2002	Captured in 2001 and 2002	First captured in 2002
Captured in 2003		3.00	12.00	84.00
Captured in 2002, not in 2001		1.00	0.00	2.00
χ^2 = 7.296, 2 df, P = 0.026	$\hat{p} \rightarrow$	0.75	1.00	0.977

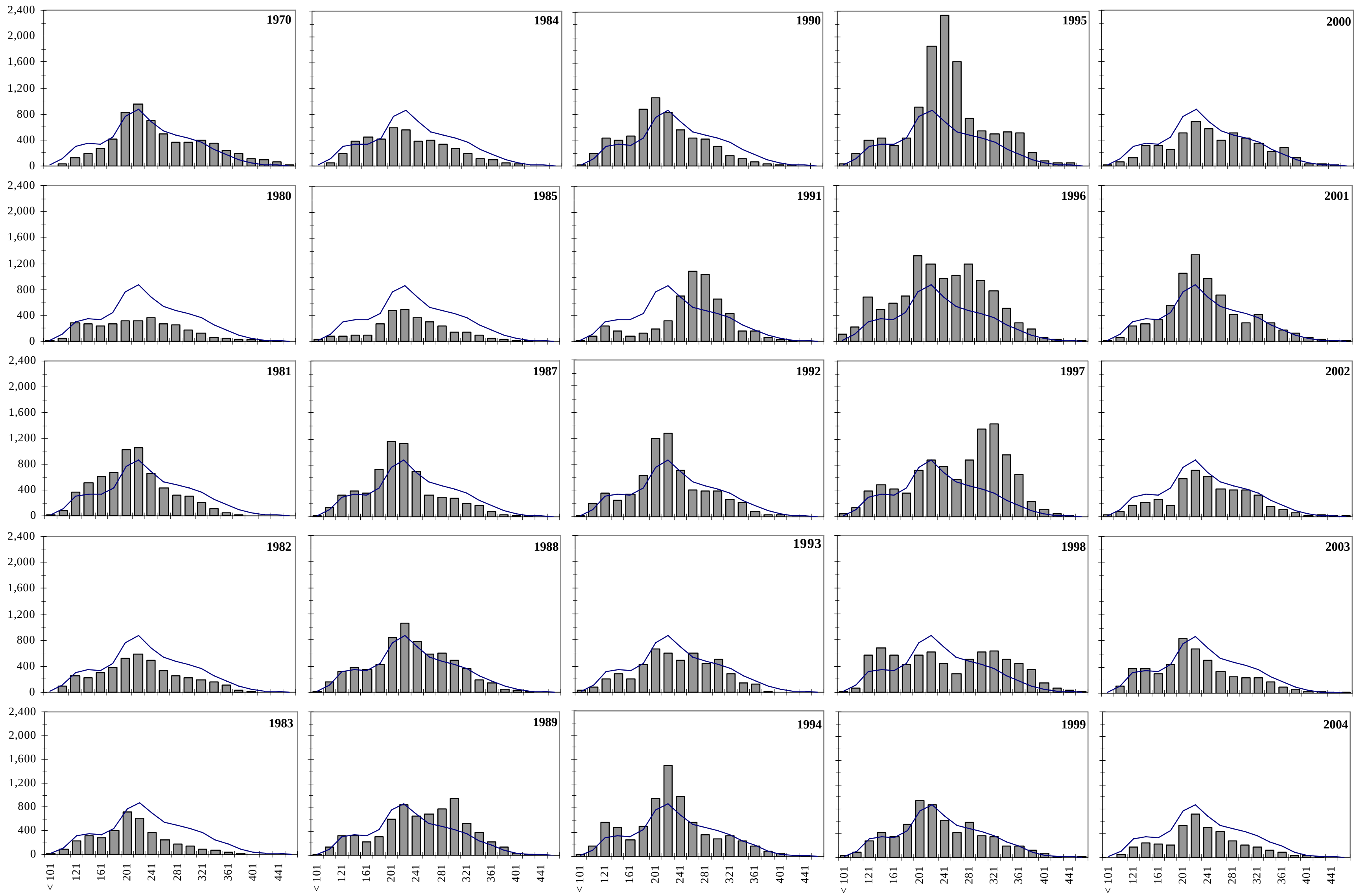
Appendix A6.–Summary of capture probabilities by tag group and sampling year for the Jolly-Seber experiment at Auke Lake. See Appendix A5 for details leading to these statistics.

	Component 1		Component 2		
Year (trips)	First captured before sample *i*	First captured in sample *i*	Captured in *i*-2, not in *i*-1	Captured in *i*-2 and *i*-1	First captured in *i*-1
1998 (1–3)	-	-	-	-	-
1999 (1,2)	0.091	0.285	-	-	-
2000 (1,2)	0.106	0.207	1.000	1.000	0.936
2001	0.122	0.214	0.667	0.300	0.829
2002	0.207	0.428	0.938	1.000	0.927
2003	0.172	0.262	0.750	1.000	0.977
2004	-	-	-	-	-
Mean	0.140	0.279	0.839	0.825	0.917

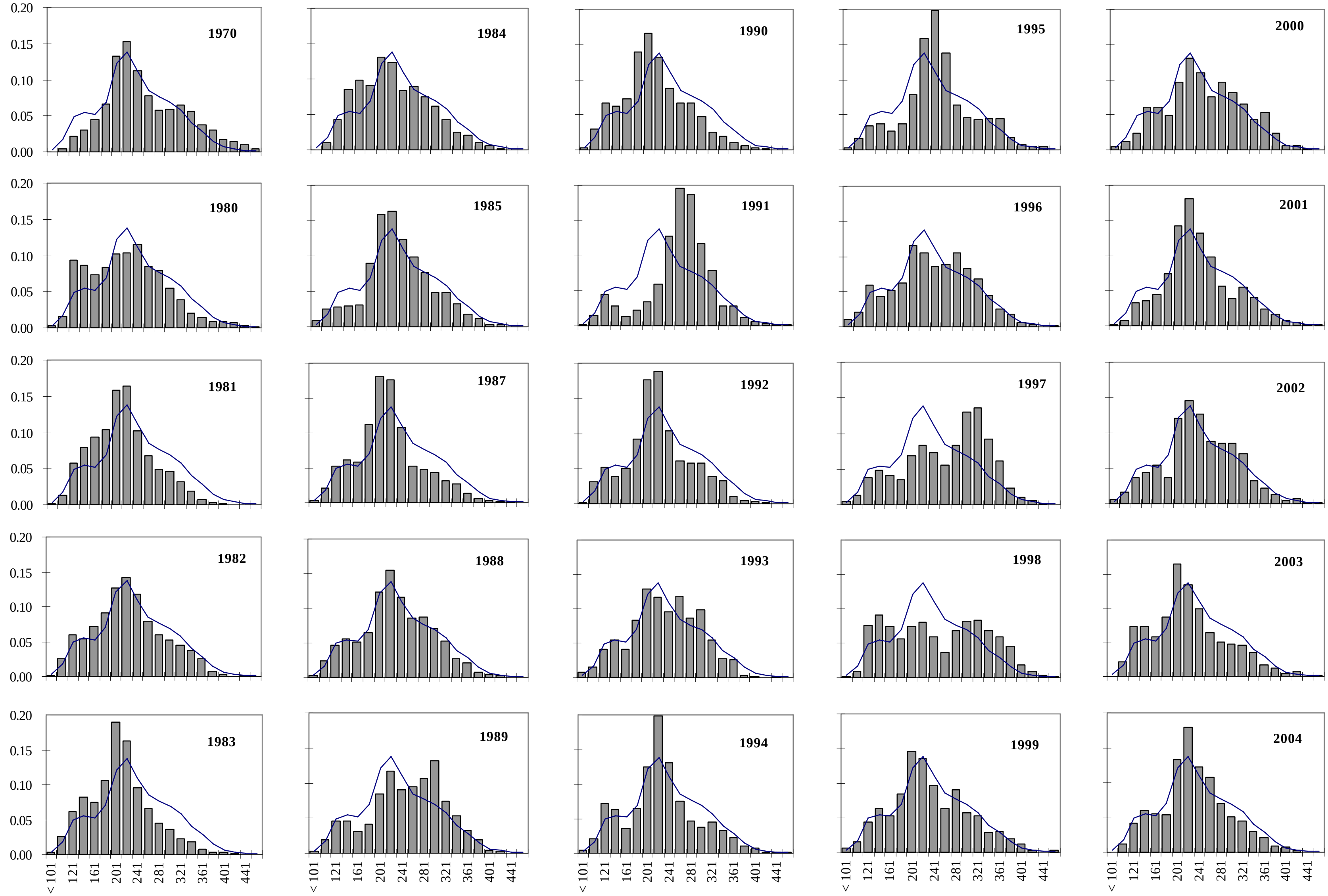
Appendix A7.–List of computer data files archived from this study.

Data File	Description
Cuts04.xls	Excel file of length information for emigrant and immigrant cutthroat trout, Auke Creek weir, 2004.
Down2004.xls	Excel file of the counts of emigrant salmonids at Auke Creek weir, 2004.
DV2004.xls	Excel file of the lengths of marked and unmarked Dolly Varden emigrating at Auke Creek weir, 2004.
spct04.xls	Excel file of recovered tagged cutthroat trout with lengths and growth information for the 2004 field season.
Lake04.xls	Excel file of cutthroat trout PIT tagging information for the abundance study in Auke Lake, 2004.
Pit04.xls	Excel file of PIT tagging information from spring tagging and fall recoveries of cutthroat trout at Auke Creek weir, 2004.
Up2004.xls	Excel file of the counts of immigrant salmonids at Auke Creek weir, 2004.

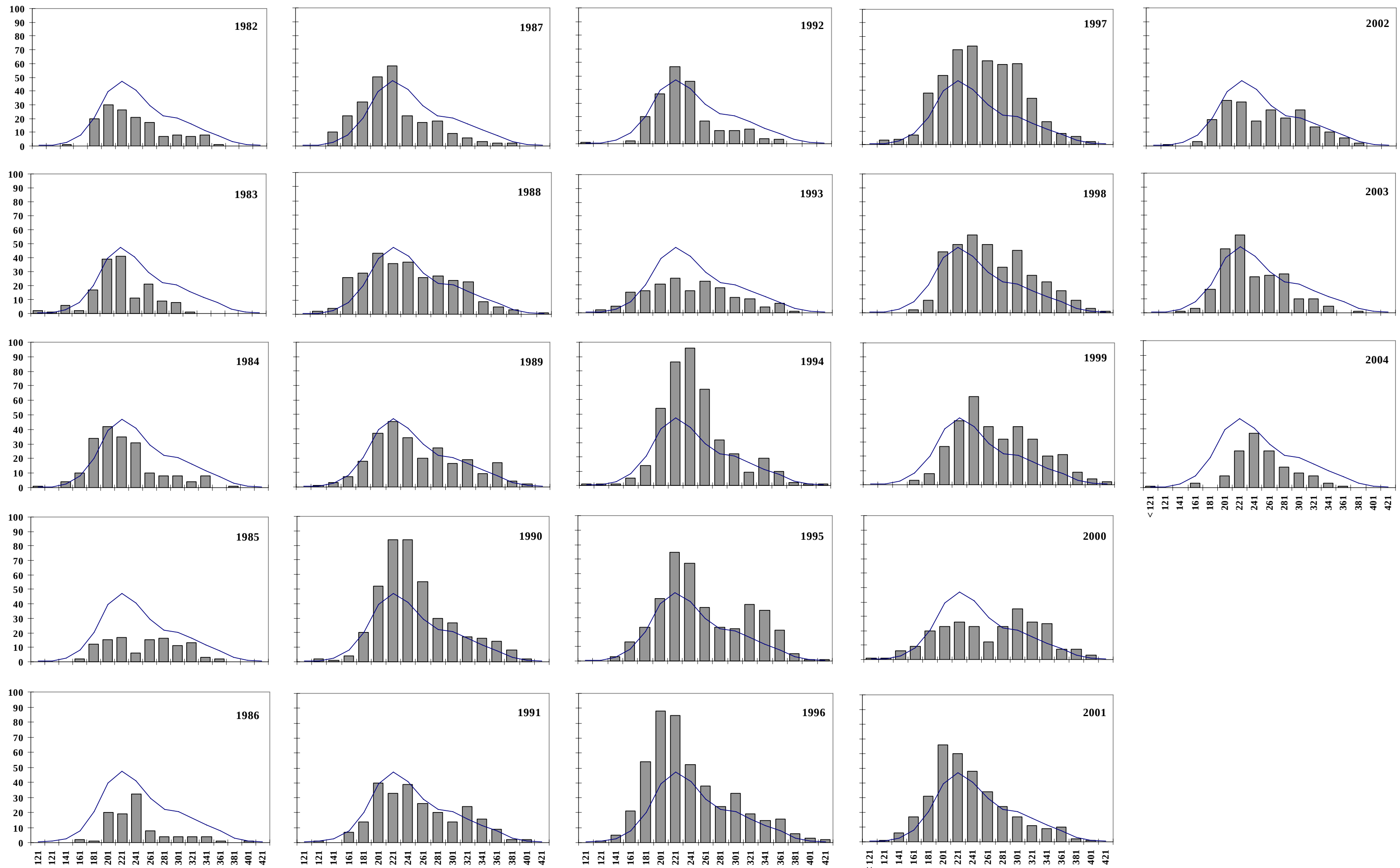
Appendix A8.–Numbers of Dolly Varden emigrating from Auke Creek by size class (<101–461 mm at 20 mm intervals) from 1970 through 2004. The solid line in each plot represents the average across all years. The x-axis is labeled using the starting length of each 20 mm interval.



Appendix A9.–Length composition (at 20 mm intervals) of Dolly Varden emigrating from Auke Creek from 1970 through 2004. The solid line in each plot represents the average across all years. The x-axis is labeled using the starting length of each 20 mm interval.



Appendix A10.–Numbers of cutthroat trout emigrating from Auke Creek by size class (<120 to >421 mm at 20 mm intervals) from 1982 through 2004. The solid line in each plot represents the average across all years. The numbers are for wild cutthroat trout only. The x-axis is labeled using the starting length of each 20 mm interval.



Appendix A11.–Length composition (in 20 mm intervals) of cutthroat trout emigrating from Auke Creek from 1982 through 2004. The solid line in each plot represents the average across all years. The numbers of cutthroat trout are for wild cutthroat trout only. The x-axis is labeled using the starting length of each 20 mm interval.