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

by

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and

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March 2006

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska 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. 06–09

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ABSTRACT

The Auke Creek weir near Juneau, Alaska, was operated in 2003 to count migrating sea-run Dolly Varden *Salvelinus malma*, cutthroat trout *Oncorhynchus clarkii*, and other species of Pacific salmon *Oncorhynchus spp*.

The number of Dolly Varden emigrants, 5,067, was the second lowest since 1986, and below the annual average of 6,305. The number of Dolly Varden immigrants, 3,978, was the second lowest observed since accurate immigration counts for this species began in 1997. Average fork length of emigrant Dolly Varden was 235 mm (SD = 69 mm). The numbers of emigrant and immigrant cutthroat trout were 254 and 129, respectively. Average fork length of emigrant cutthroat trout was 255 mm (SD = 48 mm). Estimated abundance of cutthroat trout ≥180 mm FL in Auke Lake was 329 (SE = 23) in spring 2002; this estimate is lower than 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, Petersen model, Jolly-Seber model.

INTRODUCTION

The Auke Lake system, north of Juneau, Alaska, has native populations of Dolly Varden *Salvelinus malma*, cutthroat *Oncorhynchus clarkii* 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, in addition to several other species, all immigrant Dolly Varden and cutthroat trout (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 a seasonal biologist 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; Lum and Taylor 2004; Neimark 1984a, 1984b; Taylor and Lum *Unpublished* 1999, 2000, 2001, 2002, 2003, 2004). An annual report for Auke Creek weir summarized the operations and fish counts for 2003 (Taylor and Lum *Unpublished* 2004).

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 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 Creek were counted in 1970 and since 1980, have been counted annually. There were four 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.

Table 1.–Average number of migrant fish counted at Auke Creek, 1980–2003. Hatchery Chinook salmon are not allowed to move above Auke Creek weir.

Annual average	Pink salmon	Coho salmon	Sockeye Salmon	Chum salmon	Chinook salmon	Dolly Varden	Cutthroat trout	Steelhead
Spring	106,393	6,190	17,073	4,120	0	6,305	260	9[a]
Fall	11,171	744	3,439	1,174	243[b]	4,520[a]	248[a]	3[a]

[a] Average of 1997–2003 weir counts, when these species were tallied.

[b] Average of 1987–2003 weir counts; fish are sacrificed at the weir.

Table 2.–Estimates of sport fishing effort, total catch, and harvest of Dolly Varden and cutthroat trout in the Auke Creek drainage, 1990–2002. 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 ADF&G/Research and Technical Services, Anchorage).

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

[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 Dolly Varden and cutthroat trout in the marine areas surrounding Auke Creek, 1990–2002. 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/Research and Technical Services Anchorage).

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

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 one 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 seawater 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). 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.

The first significant trout tagging program at Auke Creek began in 1994 when fish leaving Auke Lake were captured and visual-implant (VI) tagged at the weir. This was followed with the implementation of passive integrated transponder (PIT) tagging at the weir in 1997. Fish tagged leaving Auke Lake in spring 1997 were recovered by anglers in marine waters over the next few summers, suggesting that Juneau roadside fisheries for anadromous cutthroat trout (Table 3) partly depend on stocks that overwinter or reside in Auke Lake. A mark-recapture program to estimate annual spring or summer abundance in Auke Lake began in 1998, after a pilot study in 1997.

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. Growth rates on individual cutthroat trout allow managers to set size-based harvest regulations and describe recruitment into the harvestable size class. Tracking the migration histories of individual fish in and out of the lake allow 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 to 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 2003, and estimate abundance of cutthroat trout residing in Auke Lake. Our objectives were to:

1. Count all cutthroat trout and Dolly Varden entering Auke Lake from July through October 2003;
2. Measure each cutthroat trout entering Auke Lake, July through October 2003;
3. Count all cutthroat trout and Dolly Varden leaving Auke Lake, March through June 2003;
4. Measure each cutthroat trout and estimate the mean length of Dolly Varden leaving Auke Lake, March through June 2003;
5. Estimate the abundance and mortality of cutthroat trout residing in Auke Lake during spring 2002 by sampling during one 10-day trip using the multi-event Jolly-Seber model.

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. Auke Creek weir is 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.

METHODS

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. The weir panels were modified to capture small Dolly Varden and cutthroat trout. 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 fish. 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 entrance 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 trout were counted and released upstream, except that early in the immigration, cutthroat trout were released below the weir to reduce the incidence of injury and death due to low stream flows, high temperatures, and the fish’s fragile condition (Lum et al. 1998). Dolly Varden were examined for adipose fin clips and 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 past work indicated that high levels of mortality could result (ADF&G unpublished data from 1996).

Marine growth and residence of cutthroat trout leaving Auke Creek in 2003 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 fork length 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 since implanting.

EMIGRANT POPULATIONS

The Auke Creek weir was operated from March 3 through June 30, 2003, 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 Floy[1] tags and adipose fin marks. Length composition was estimated using a systematic sampling procedure. The fraction p_k of Dolly

[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement.

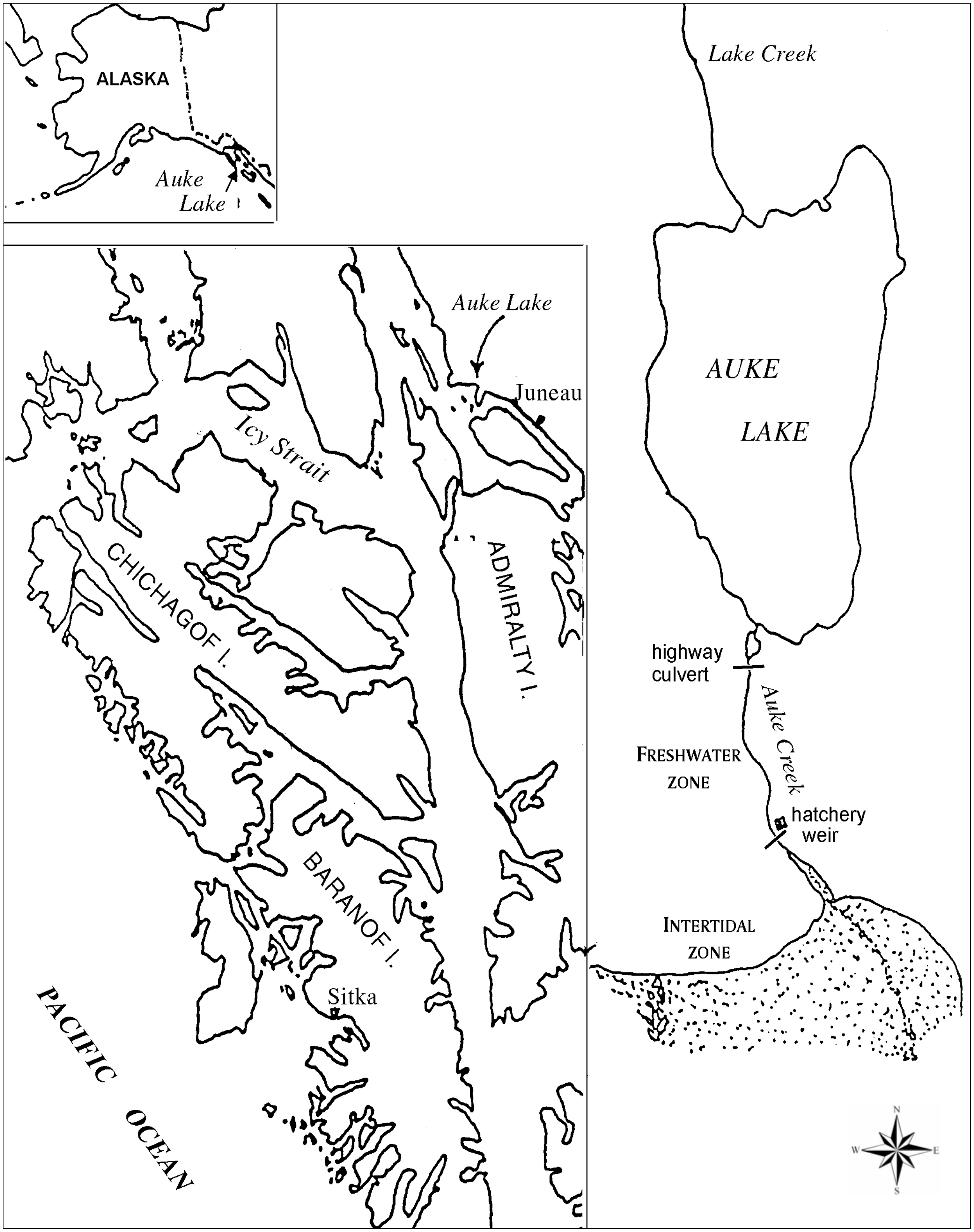

Figure 1.–The Auke Lake system in northern Southeast Alaska and location of the Auke Creek weir.

Varden in size increments emigrating from Auke Lake was estimated:

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

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

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

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

$$se(\hat{p}_k) = \sqrt{\text{var}(\hat{p}_k)} \quad (3)$$

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

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

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

$$\text{var}(\hat{N}_k) = N^2(\text{var}(\hat{p}_k)) \quad (5)$$

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

$$se(\hat{N}_k) = \sqrt{\text{var}(\hat{N}_k)} \quad (6)$$

Daily, every 10th Dolly Varden captured was measured to the nearest 5 mm from the tip of snout to fork of tail (FL). Average length of Dolly Varden emigrants sampled at the weir was estimated:

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

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

$$se(\bar{y}) = \sqrt{\left(1-\frac{n}{N}\right)\frac{1}{n(n-1)}\sum_{i=1}^{n}(y_i-\bar{y})^2} \quad (8)$$

where N is the weir count. The finite population correction factor (fpc) of $1-\frac{n}{N}$ 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 Floy or visual implanted (VI) tags and missing fins. In 2003, marked cutthroat trout included: (1) adipose-clipped fish carrying a PIT tag placed between 1997 and 2003; (2) VI tagged and adipose-clipped fish marked during emigrations from the lake in 1994–1996; (3) left ventral-clipped hatchery fish released in 1994; (4) right ventral-clipped hatchery fish released in 1991; and (5) adipose-clipped hatchery fish released in 1986 and 1987. All cutthroat trout missing the 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 and prevent tag loss and infection. Newly tagged cutthroat trout were held for 24 hours to evaluate short-term tag loss and handling mortality.

As a task, all cutthroat trout mortalities were sampled to collect FL, scales, otoliths, and gender, 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.

CUTTHROAT TROUT IN AUKE LAKE

Abundance, survival, and birth rates of cutthroat trout ≥180 mm FL in Auke Lake were estimated in 1998, 1999, 2000, 2001, and 2002 using the "full" Jolly-Seber (JS) model (Seber 1982), which provides k-2 abundance estimates and k-2 survival rate estimates (k = number of sampling events). Two JS analyses were made: one with data aggregated by sampling trip to yield a 10-event (by trip) model, and one with data pooled by sampling year to yield a 6 event (by year) model. Fish captured several times during a sampling period were treated as being caught only once. Data for the analysis was 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. Parameter estimates were constrained to admissible values (if necessary) in POPAN using procedures in Schwarz et al. (1993) and Schwarz and Arnason (1996). 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, and one trip was made in June for 2002 and 2003. 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 and 2003, sampling was scheduled during June to follow the anadromous emigration and precede summer conditions characterized by elevated water temperatures to levels that could be dangerous to fish captured and tagged in the study.

We attempted to capture cutthroat trout using two types of traps baited with Chinook salmon eggs, and by hook and line fishing with small spoons, spinners, and other lures. 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. Hook-and-line sampling was typically conducted during daylight hours after the traps were checked. Hook-and-line sampling continued until the sampling effort goal was met (i.e., 20 rod hours over a 9-day sampling event). Fish caught with hook-and-line gear were sampled and tagged; processing time was not included in the effort tally. Anglers were made up staff who had participated in the actual lake trapping. 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 red dye mark on the left ventral fin, and had their adipose fin excised. Fish caught more than once during the sampling trip 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 8 areas to facilitate sampling and accurate recording of locations where cutthroat trout were captured (Figure 2). Data from these areas were then pooled into 3 strata (A, B, C) for testing experimental assumptions. Trapping and hook and line sampling were 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; NMFS unpublished data, Juneau, Alaska). All traps were fished each day using a fathometer to determine depth. Overall fishing effort (number of traps set and hours of hook and line effort) in each area was proportional to the lake surface area where depth was ≤15 m (Table 4). The depth, sampling area, and number of fish caught were recorded by trap set.

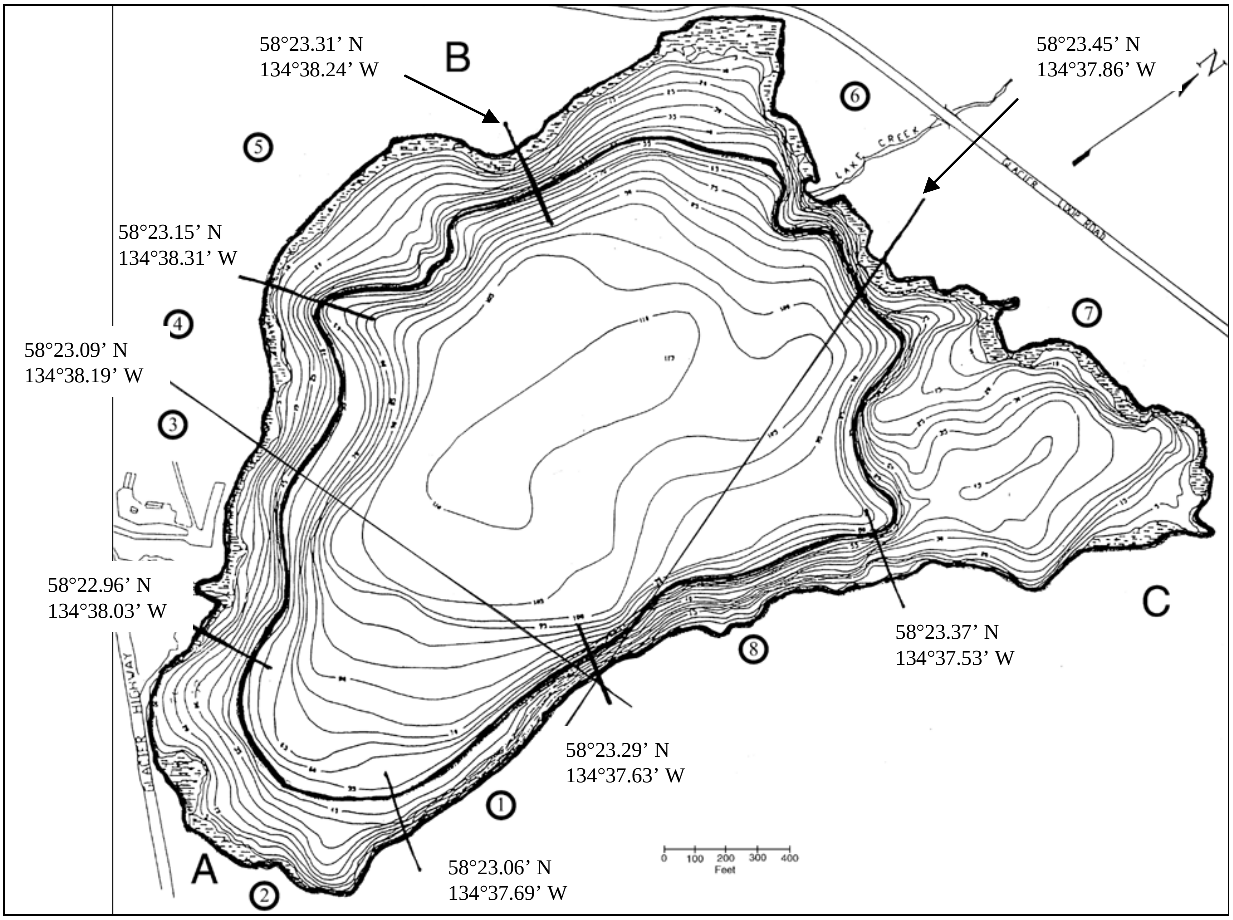

Figure 2.–Bathymetric map of Auke Lake showing location of sampling areas in 2003. The lake area inside the inner bold line denotes depths >15 m that are excluded from sampling. The two intersecting straight lines indicate the separation between the three strata (A, B, and C) used in analysis.

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 goodness-of-fit (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, but 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

Table 4.–Distribution of sampling effort in Auke Lake by area in 2003. 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 and 20 rod-hours over the 9-day sampling trip.

Area No.	Analysis stratum	Area[a] (km^2)	Proportion[a]	Hook and line effort (hrs)	No. of traps set each day	Total trap effort (sets)
1	A	0.5463	0.0459	1:00	1	9
2	A	2.6098	0.2195	4:23	3–4	29
3	A	1.0583	0.0890	1:47	2–1	18
4	B	0.8275	0.0696	1:23	1	9
5	B	1.4691	0.1236	2:28	2	18
6	B	1.4562	0.1225	2:27	2	18
7	C	3.1297	0.2632	5:16	4	36
8	C	0.7932	0.0667	1:20	1	9
Totals		11.8901	1.0000	20:04	16	146

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

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 3 x 3 contingency table, $\alpha = 0.05$) was used for the test.

The equal probability of capture assumption can 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 dependent mortality rates for cutthroat trout ≥180 mm FL. We do not test for this, but little evidence of age-dependent mortality was found for cutthroat trout ≥180 mm FL in Florence Lake (Rosenkranz et al. 1999).

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 in the annual trip-by-trip model. However, a large emigration during or between trips would contribute to violation of this assumption. Also, for years 1998–2000, estimates of significant "birth" and/or "mortality" rates between sample periods within a year would suggest violation of assumption 5.

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:

$$s\hat{e}(\hat{p}_k) = \sqrt{\hat{\text{var}}(\hat{p}_k)} \quad (11)$$

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:

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

The standard error of N_k was estimated:

$$s\hat{e}(\hat{N}_k) = \sqrt{\hat{\text{var}}(\hat{N}_k)} \quad (14)$$

RESULTS

MIGRANT DOLLY VARDEN

A total of 5,067 Dolly Varden emigrated in 2003. The emigration was the eighth lowest run in 24 years (Table 5; Figure 3) and below the previous 23-year average of 6,359 (SD = 2,358). The Dolly Varden emigration has been in decline since 1995 when the emigration through the weir was 11,732. The first Dolly Varden was captured March 5 and the last June 27 (Figure 4; Appendix A1). The midpoint of the emigration (May 3) was 6 days earlier than the historical average of May 9 (range April 30 to May 24; Table 5). Average fork length of emigrant Dolly Varden in 2003 was 235 mm (SD = 69 mm), and ranged from 110 to 465 mm. Average length generally declined during the emigration (Figure 5). Only 1.4% of the emigration was estimated to be ≥400 mm FL (Table 6; Figure 6).

The Dolly Varden immigration of 3,978 fish began on July 2, shortly after the upstream trap was installed, and the last fish was captured October 30 when the weir was removed (Figure 4; Appendix A2). This was the second lowest count since upstream migration of Dolly Varden was first monitored in 1997. Immigration counts for 1997–2002 were 5,705, 4,993, 4,709, 3,665, 4,249, and 4,341 and the average was 4,520, excluding the current year. Major peaks in immigration occurred intermittently in early September, following heavy rainfall.

Table 5.–Annual counts and mid-points of the spring emigration of wild Dolly Varden and cutthroat trout at Auke Creek, 1980–2003. Hatchery-produced or lake-stocked cutthroat trout are not included in this table.

Year	Dolly Varden	Midpoint of emigration	Cutthroat trout	Midpoint of emigration
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	5-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	418	12-May
1998	7,532	1-May	336	11-May
1999	6,393	14-May	341	16-May
2000	5,254	6-May	249	13-May
2001	7,356	12-May	337	20-May
2002	4,858	12-May	210	20-May
2003	5,067	3-May	254	11-May
Mean	6,305	9-May	260	16-May

MIGRANT CUTTHROAT TROUT

A total of 254 cutthroat trout emigrated in 2003, slightly below the previous 23-year average of 261 (SD = 114) wild fish (Table 5; Figure 7). The emigration of cutthroat trout leaving Auke Lake has been declining since 1996. The first emigrant was captured April 2 and the last June 24 (Figure 8; Appendix A1). The midpoint of emigration (May 11) was 5 days earlier than the historical average of May 16 (range May 7 to May 31; Table 5). Water temperatures during the emigration in 2003 ranged between 2.9° and 16.0°C. Overall, water temperatures were above average through mid-June.

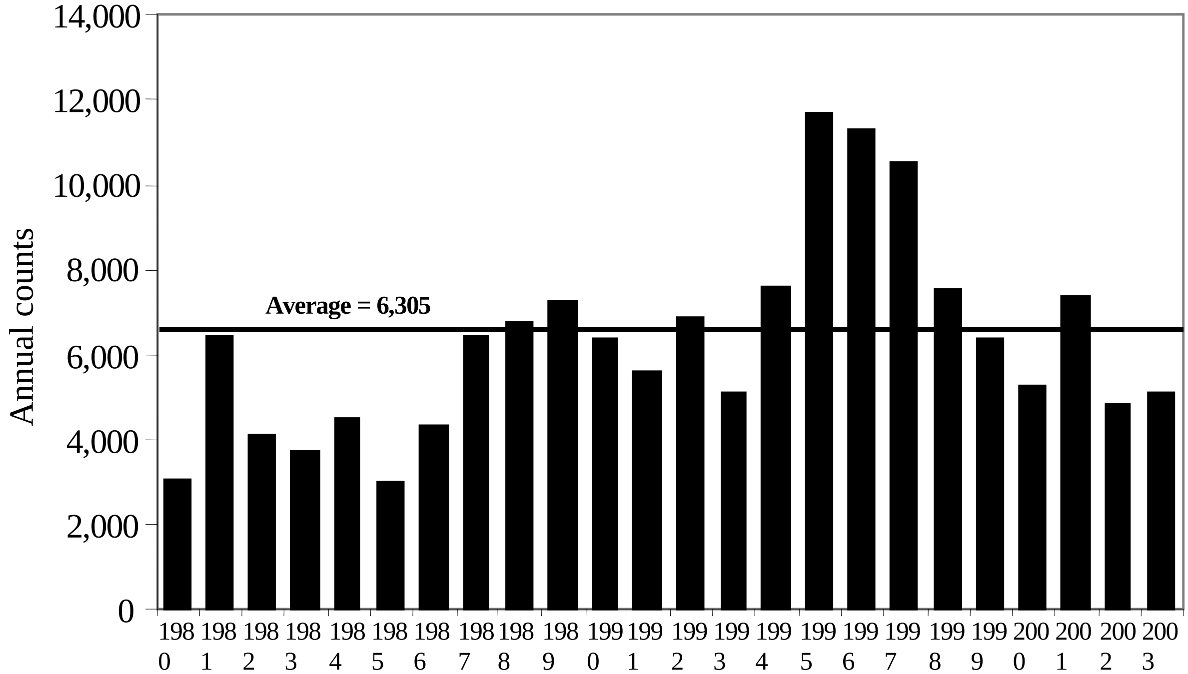

Figure 3.–Annual emigration counts of Dolly Varden at Auke Creek, 1980–2003.

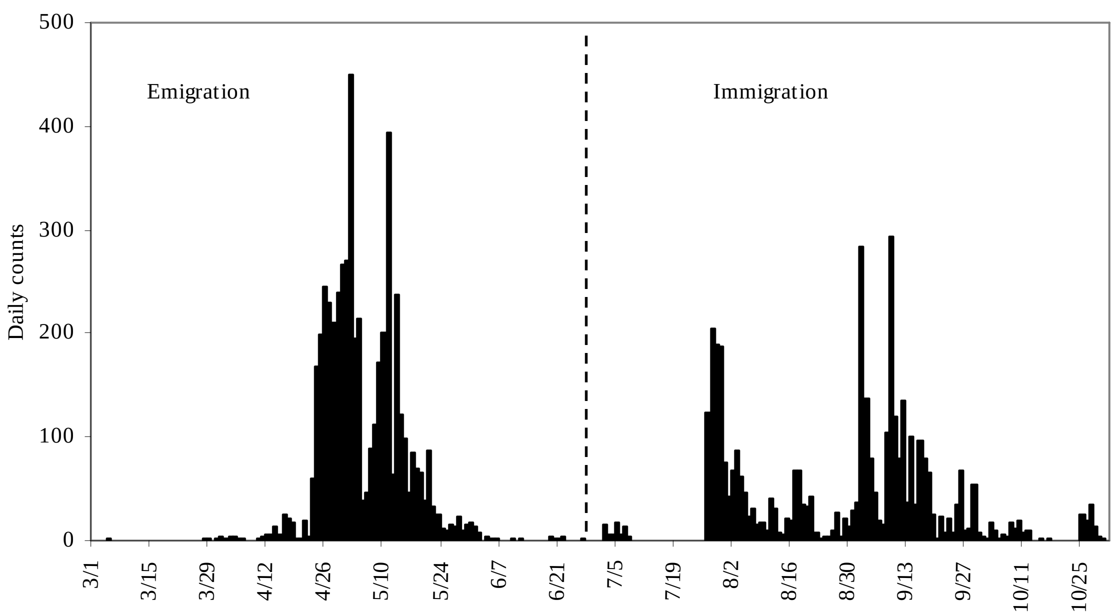

Figure 4.–Emigration and immigration counts of Dolly Varden at Auke Creek in 2003. The vertical dashed line marks June 30, when the weir was converted to count fall immigrants.

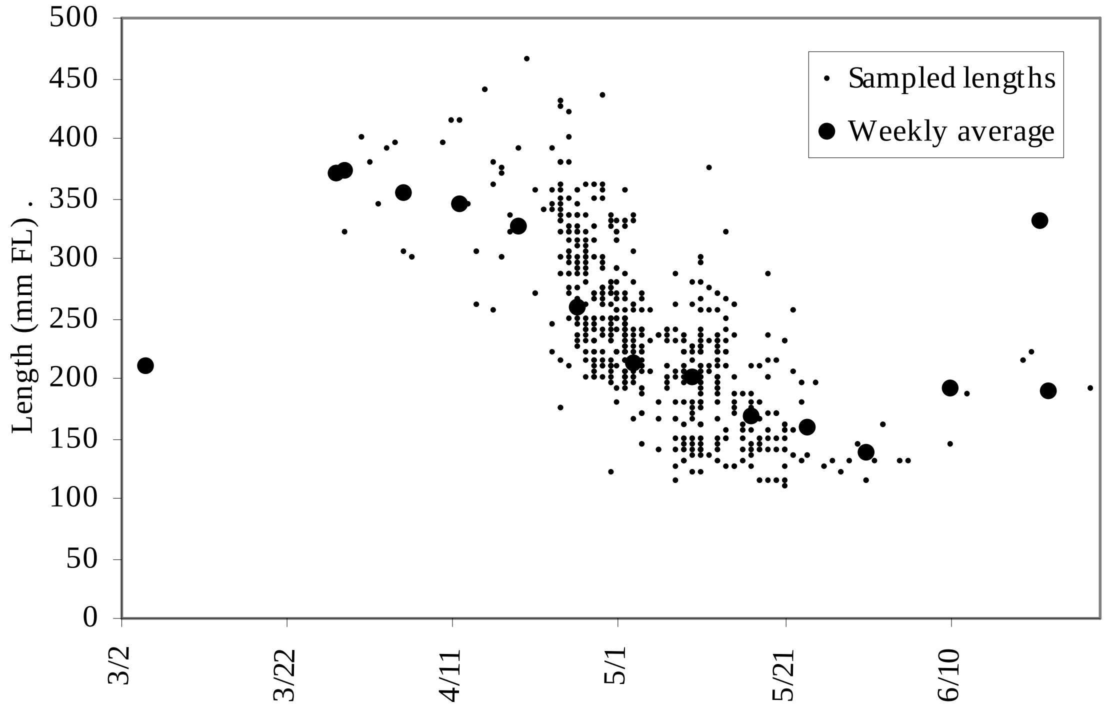

Figure 5.–Dolly Varden lengths (mm FL) versus date during the spring emigration at Auke Creek in 2003. Average fish lengths during each week are overlaid on the sample data.

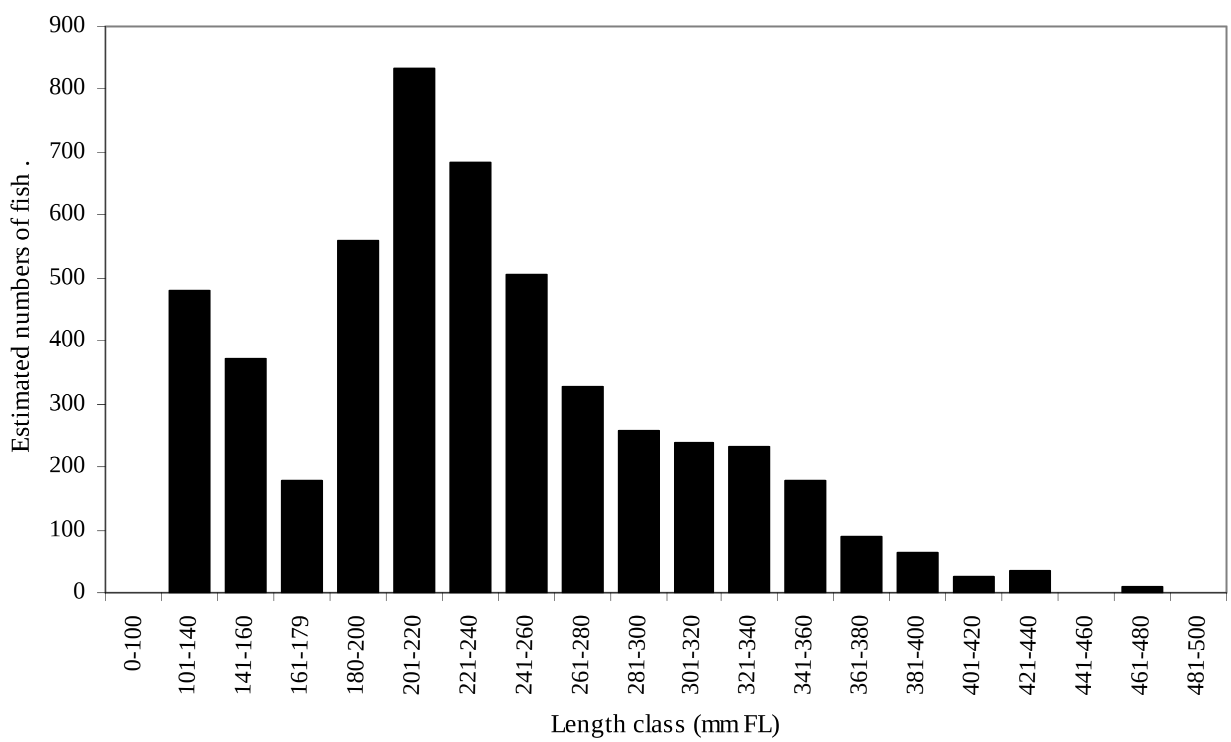

Figure 6.–Estimated length composition of emigrating Dolly Varden at Auke Creek in 2003. Estimated abundance at length are shown for 20-mm length class.

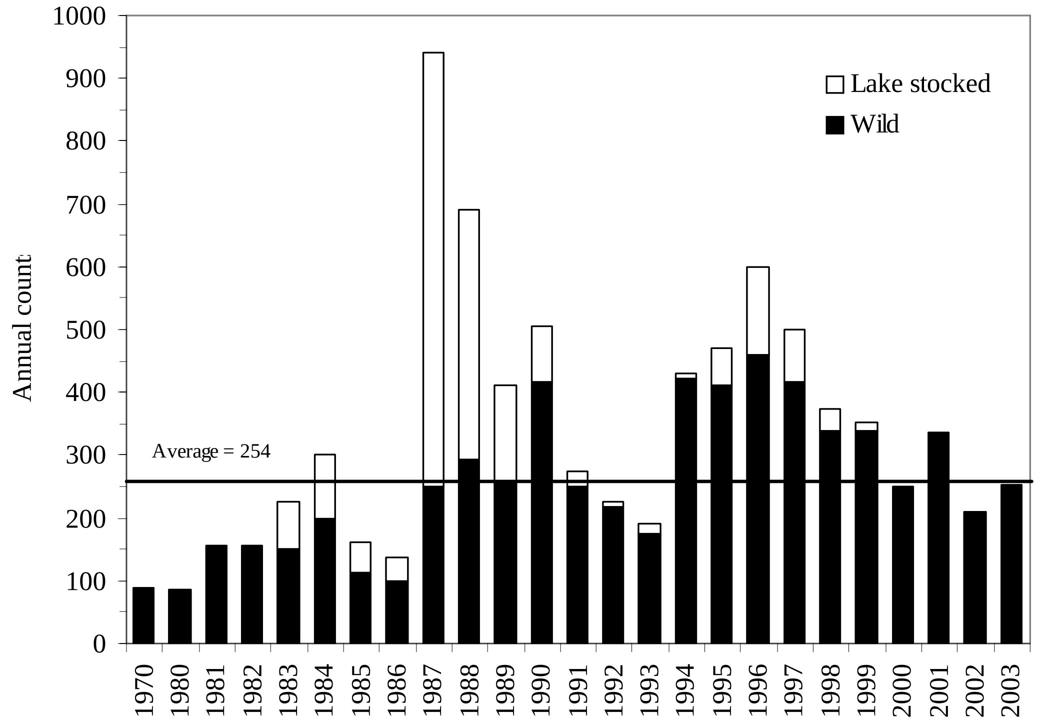

Figure 7.–Annual spring emigration of cutthroat trout at Auke Creek, 1980–2003. Hatchery cutthroat trout were stocked in Auke Lake in 1983 (1,286 right ventral marked and 4,078 left ventral marked fish); 1986 (3,489 adipose marked fish); 1987 (1,1719 adipose marked fish); 1991 (2,465 right ventral marked fish); and 1994 (3,098 left and right ventral marked fish).

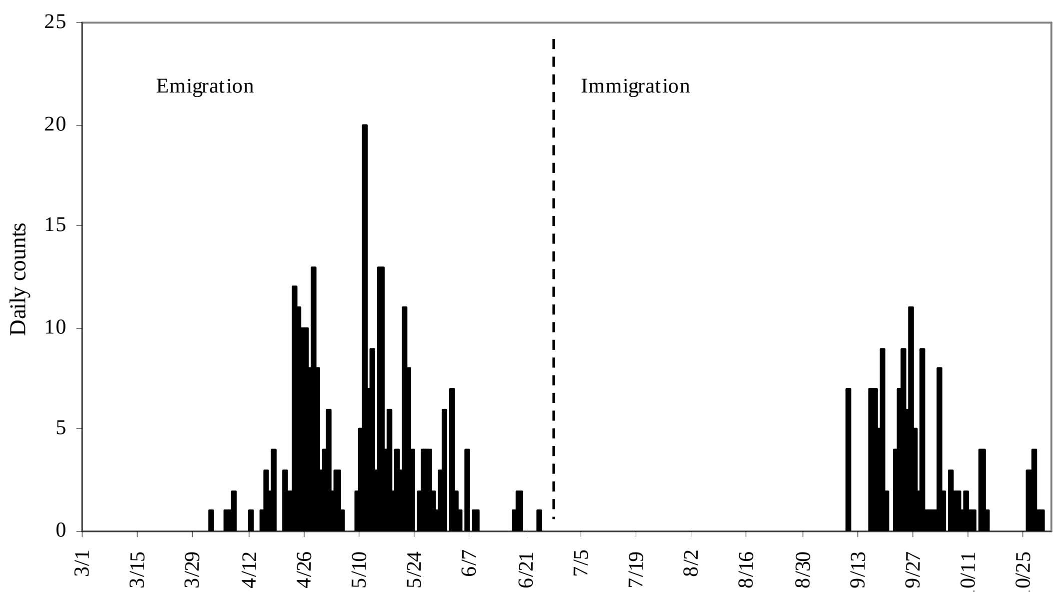

Figure 8.–Spring emigration and fall immigration counts for cutthroat trout at Auke Creek in 2003. The vertical dashed line marks June 30, when the weir was converted to count fall immigrants.

Table 6.–Length composition and estimated abundance at length for emigrating Dolly Varden at Auke Creek in 2003. 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.

Length *k*, mm FL	n_k	$\hat{p}_k$	$S\hat{E}(\hat{p}_k)$	$\hat{N}_k$	$S\hat{E}(\hat{N}_k)$
0-100	0	0.000	0.000	0	0.00
101-140	54	0.095	0.012	479	58.50
141-160	42	0.074	0.010	373	52.19
161-179	20	0.035	0.007	177	36.75
180-200	63	0.110	0.012	559	62.64
201-220	94	0.165	0.015	834	74.14
221-240	77	0.135	0.013	683	68.28
241-260	57	0.100	0.012	506	59.93
261-280	37	0.065	0.010	328	49.21
281-300	29	0.051	0.009	257	43.89
301-320	27	0.047	0.008	240	42.43
321-340	26	0.046	0.008	231	41.68
341-360	20	0.035	0.007	177	36.75
361-380	10	0.018	0.005	89	26.22
381-400	7	0.012	0.004	62	22.00
401-420	3	0.005	0.003	27	14.45
421-440	4	0.007	0.003	35	16.67
441-460	0	0.000	0.000	0	0.00
461-480	1	0.002	0.002	9	8.36
481-500	0	0.000	0.000	0	0.00
n =	571		*N* =	5,067	

The cutthroat trout emigration included 80 fish missing their adipose fin; the remainder was not fin marked or tagged (including one fish that escaped). One fish missing an adipose fin had a missing or non-operational PIT tag, yielding a tag retention rate of 99%. The 79 marked fish with a PIT tag included 78 that were tagged in 2002 or earlier and one fish tagged in Auke Lake during the lake abundance project in June 2003. Average fork length for emigrant sea-run cutthroat trout was 255 mm (SD = 48 mm) and ranged from 147 to 417 mm. The average length of all cutthroat trout emigrants generally declined during the emigration (Figure 9). The emigration comprised 14% males, 17% females, and 69% that showed no obvious signs of gender (extruded vent or release of gametes upon capture). Twenty-five percent of the emigrants were obviously ripe (ready to spawn), 52% of which were male and 47% female. Ripeness of maturing fish started to decline after the end of April and the last ripe fish was seen on May 14.

A total of 129 cutthroat trout were passed through the immigrant weir (Figure 8; Appendix A2). Cutthroat trout immigrations were first documented in 1997 and counts for 1997–2002 were 467, 361, 205, 105, 228, and 241. Cutthroat trout were first passed upstream of the weir in September. Because some of the earlier migrant trout were released downstream from the weir earlier, returned, and were not released upstream until they looked capable of remaining in fresh water, the timing data is biased. This appears unavoidable because releasing fish above the weir too early results in high mortality.

A total 125 fish were examined for marks and tags. Of these, 28 were adipose clipped and had an operating PIT tag. PIT tag retention was 100%. Immigrant cutthroat trout averaged 243 mm FL (SD = 47 mm), ranging from 128 to 361 mm. Average lengths of immigrating cutthroat trout did not vary greatly over time (Figure 10). The length frequency distribution for both spring and

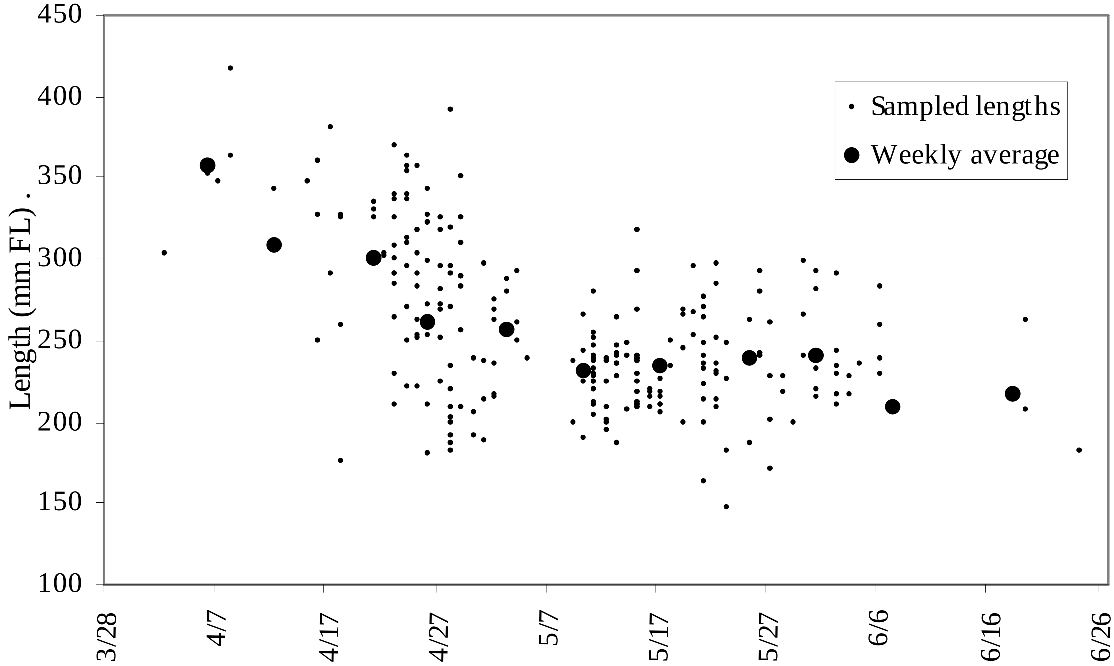

Figure 9.–Cutthroat trout lengths (mm FL) by date during the spring emigration at Auke Creek in 2003. Average fish lengths during each week are overlaid on the sample data.

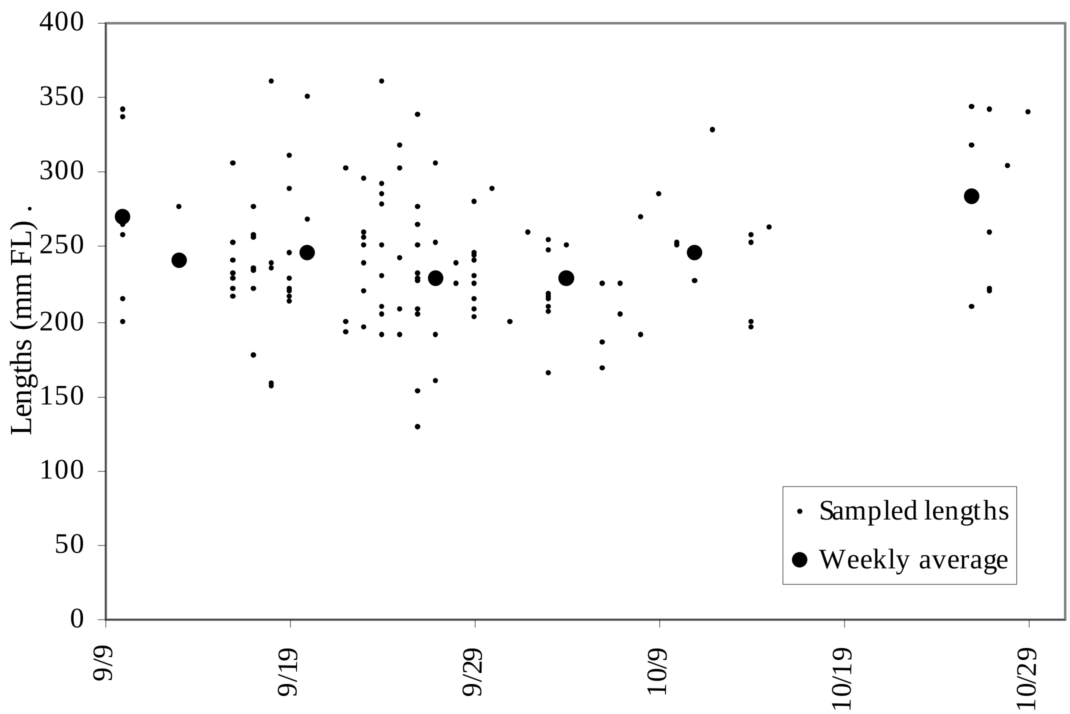

Figure 10.–Cutthroat trout lengths (mm FL) by date during the fall immigration at Auke Creek in 2003. Average fish lengths during each week are overlaid on the sample data.

fall migrants is skewed towards shorter lengths (Figure 11) and few trout met the 14 inch (356 mm) minimum size limit for Auke Lake.

Marine growth and 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 59 mm FL (SE = 3 mm) and ranged from 30 to 89 mm. The average growth rate during this period was 0.44 mm/day (SE = 0.025). This rate was similar to that in the last six years (Lum and Taylor 2004). Marine growth rates (mm/day) tended to decrease as the size of the emigrating fish increased (Figure 12). PIT-tagged cutthroat trout that returned to Auke Creek in the summer and fall 2003 had an average period between emigration and immigration of 138 days (SE = 23, range 93 to 188 days) from Auke Lake. Marine residence periods of Auke Creek cutthroat trout in 1998–2002 ranged from 122–149 days (Lum et al. 1999; 2002; Lum and Taylor 2004). There was not a simple relationship between emigration and immigration dates in 2003 (Figure 13), but there was a strong relationship (R^2 = 0.65) between emigration date and the duration of marine residence (Figure 14).

CUTTHROAT TROUT IN AUKE LAKE

A total of 715 cutthroat trout between 98 and 354 mm FL were captured during the lake survey in Auke Lake in 2003, including 422 unique cutthroat trout ≥180 mm FL. Of the unique fish, 113 fish had been tagged in previous years and 309 fish had not been previously captured. Six fish had lost their tags (5% of the marked sample). A total of 269 fish were captured more than once in 2003 and were considered "redundant" within this sampling event/year. The largest numbers of fish caught were ≥ 180 mm (Table 7); in the 180-200 mm and 221-240 mm FL size classes (Table 7; Figure 15) Capture histories and summary statistics for sampling since 1998 were compiled for both annual (year-by-year) and trip-by-trip JS analyses (Appendix A3; Table 8).

Mixing was complete from 2002 to 2003 (Appendix A4). Complete mixing was expected across years because Auke Lake is small. Complete mixing has been observed (P > 0.05) between all successive sample years since 1999 (Lum and Taylor 2004). Overall GOF for homogeneous capture/survival probabilities by tag group (Table 9; Appendix A5) suggested the JS models did not fit the data well (p=0.001 for the annual data, p=0.020 for the trip-by-trip data). Inspection of the test results (Table 9) shows the majority of the annual GOF statistics were significant, while most of trip-by-trip statistics were not. A summary of the capture probabilities from the component-1 GOF test (Robson's test for short-term mortality) for annual data (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 test was less useful because key capture histories were absent in the annual data (because of the small sample size in 1998), and sample sizes were too small for most tests (Appendix A5).

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 "model 3" in POPAN) was, as in previous years, fit to the annual JS data. 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). Also, except for the 1999 estimate, there was little difference between abundance estimates by model type. Similarity between the estimates from each model was likely the result of high capture rates (35% to 86%). 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; $\hat{N}_{2002}$=316, SE=38) was much lower than the precision of the estimates from the full JS model (Table 10). The 1999 estimate from the generalized model (808 ± 428) appears to be much larger than the estimates from the full JS (561 ± 118) or Petersen (464 ± 23) models (Lum et al. 2001), but the difference(s) are not statistically significant (P>0.4). 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.

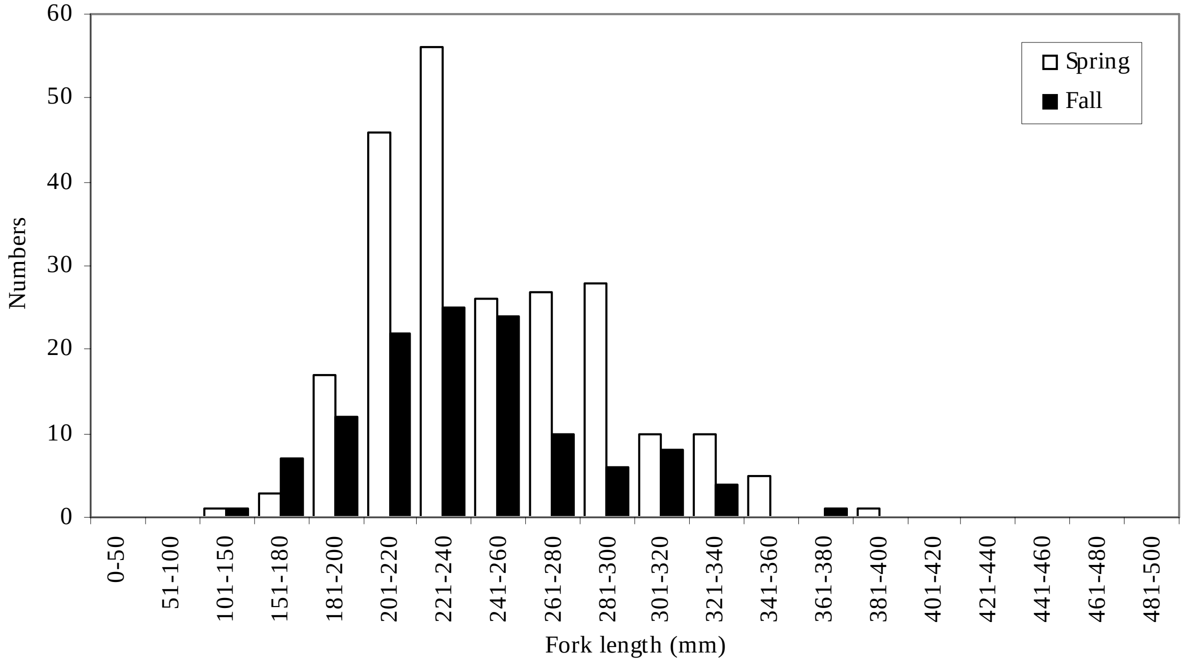

Figure 11.–Lengths of cutthroat trout, pooled by 20 mm groups, during the spring emigration and the fall immigration at the Auke Creek weir in 2003.

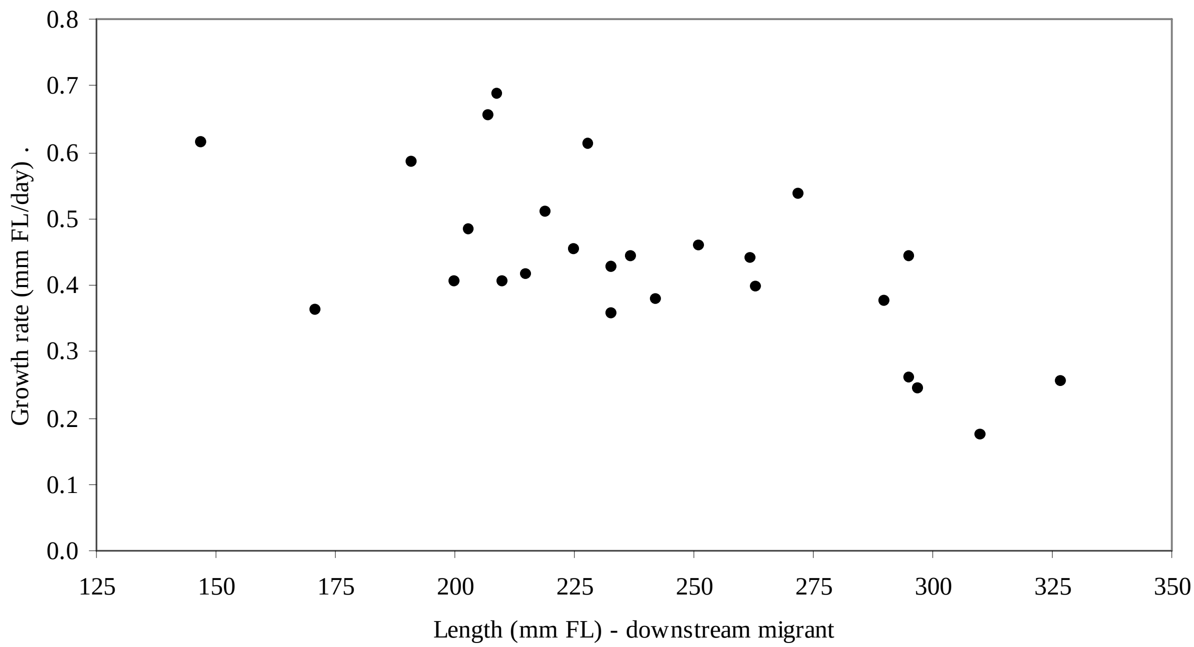

Figure 12.–Growth rate (mm FL/day) of tagged Auke Creek cutthroat trout in 2003 during the period between the spring emigration and the fall immigration versus fork length at the time of emigration in 2003.

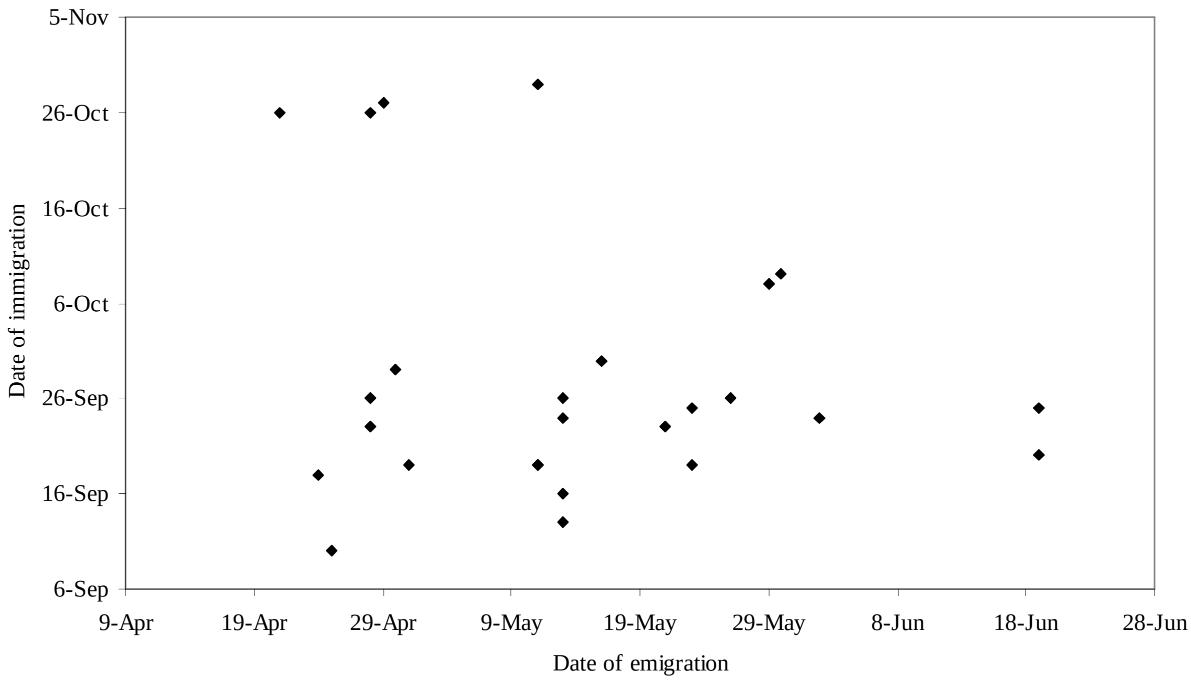

Figure 13.–Immigration and emigration dates for tagged cutthroat trout at Auke Lake in 2003

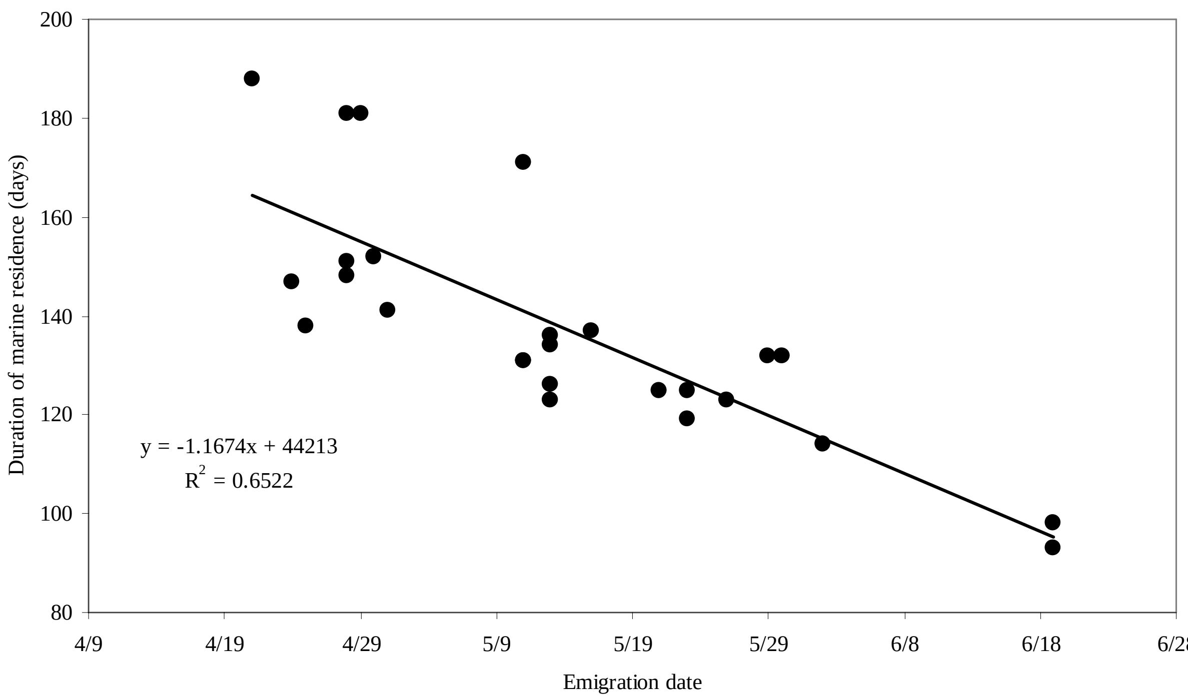

Figure 14.–Relationship between emigration date of tagged cutthroat trout from Auke Lake in 2003 and the duration of their hiatus from the lake.

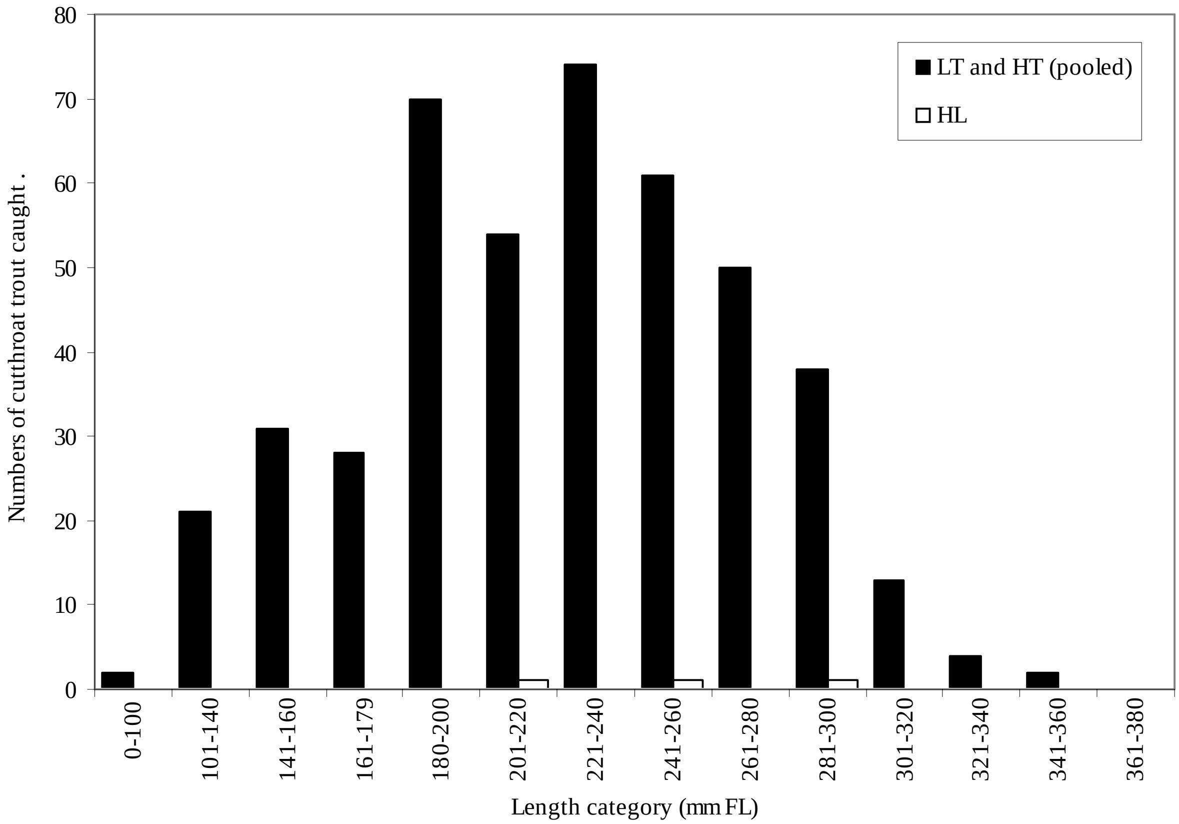

Figure 15.–Fork lengths of cutthroat trout sampled in Auke Lake by gear type in 2003. Fish captured more than once in 2003 are not plotted. LT = Large Traps, HT = Hoop Traps, and HL = Hook and Line.

Table 7.–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 2003. Redundant fish included in catch. The 2003 trip was a one-event mark and recapture.

			≥180 mm		**<180 mm**		**Combined**	
Sampling event	**Gear type**	**Efforts (hours)**	**Catch**	**CPUE**	**Catch**	**CPUE**	**Catch**	**CPUE**
June 4–13	Hook and line	20	3	0.150	0	0	3	0.150
	Large traps	3,240	600	0.185	97	0.030	697	0.210
	Hoop traps	216	7	0.032	7	0.032	14	0.065
	All gear	4,340	610	0.079	104	0.024	714[1]	0.165

1 Not including one fish for which all length and tagging data was lost.

Table 8.–Summary statistics for Jolly-Seber models, Auke Lake, 1998–2003.

Year	n_i	m_i	R_i	r_i	z_i
Annual model					
1998	89	0	89	26	0
1999	352	22	352	96	4
2000	292	94	292	51	6
2001	233	41	233	45	16
2002	259	58	259	96	3
2003	370	99	370	0	0
Trip-by-trip model					
1998 (1)	40	0	40	16	0
1998 (2)	42	4	42	18	12
1998 (3)	19	8	19	4	22
1999 (1)	192	13	192	123	13
1999 (2)	265	114	265	78	22
2000 (1)	182	51	182	103	49
2000 (2)	205	138	205	43	14
2001 (1)	233	41	233	45	16
2002 (1)	259	58	259	96	3
2003 (1)	370	99	370	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*

Table 9.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group. Asterisks denote tests which contained a cell with an expected value of less than 2. Overall chi-squares are the sum of the individual test statistics.

		Component 1		Component 2	
Year	**Period**	**Test statistic**	**P-value**	**Test statistic**	**P-value**
Annual model					
1999		3.911	0.048		
2000		4.483	0.034	0.407	0.816*
2001		1.618	0.203	11.246	0.003*
2002		8.592	0.003	0.319	0.852*
Overall by component		18.604	0.001	11.973	0.063
Overall		30.576	0.001		
Trip by trip model					
1998	2	1.865	0.172*		
"	3	0.130	0.719*	4.091	0.129*
1999	4	0.632	0.427	2.182	0.336*
"	5	0.023	0.880	3.321	0.190*
2000	6	0.002	0.964	11.528	0.003
"	7	0.507	0.477	1.697	0.428
2001	8	1.618	0.203	1.126	0.570
2002	9	8.592	0.003	0.320	0.852*
Overall by component		13.368	0.100	24.264	0.043
Overall		37.632	0.020		

Table 10.–Estimates of abundance ($\hat{N}$), survival ($\hat{\phi}$), and births ($\hat{B}$) of cutthroat trout ≥180 mm FL at Auke Lake, 1998–2002.

Year	$\hat{N}$	SE($\hat{N}$)	$\hat{\phi}$	SE($\hat{\phi}$)	$\hat{B}$	SE($\hat{B}$)
Annual model						
1998			0.411	0.088		
1999	561	118	0.349	0.045	199	48
2000	394	44	0.376	0.073	534	122
2001	682	142	0.210	0.030	148	29
2002	291	19				
Trip-by-trip model [a]						
1998 (1)			0.804	0.199		
1998 (2)	220	66	1.000[b1]	0.000[c]	0[b2]	0[c]
1998 (3)	220	66	0.410	0.080	401	115
1999 (1)	492	117	0.889	0.076	2	102
1999 (2)	439	44	0.386	0.040	232	23
2000 (1)	401	27	0.774	0.081	0[b3]	0[c]
2000 (2)	311	34	0.456	0.091	562	129
2001 (1)	704	149	0.209	0.030	148	32
2002 (1)	295	26				
2003 (1)						

a Estimates constrained to admissible values (Schwarz and Arnason 1996)

b Constrained estimates. The unconstrained values were: [b1]=1.371, [b2]=-154, [b3]=-64

c SE for constrained values not available.

Estimates of abundance, survival, and recruitment of cutthroat trout ≥180 mm FL in Auke Lake using the annual and trip-by-trip models are summarized in Table 10**.** Estimated 2002 harvests at Auke Lake (38 fish) and the surrounding marine area (7 fish) continue to be low, although the catch in the Auke Creek drainage appeared to increase in 2001 and 2002 (Table 2). Cutthroat trout ≥180 mm FL sampled in Auke lake in 2002 averaged 228 mm FL (SD = 44 mm) and ranged from 180 mm to 368 mm FL. Using the annual abundance estimate (291), 55.4% of the population in 2002 was ≤240 mm FL (Table 11). By regulation, harvest of cutthroat trout in Auke Lake is restricted to fish ≥356 mm FL (14 inches TL); one of the cutthroat trout in Auke Lake during June exceeded the 14-inch minimum size limit.

A total of 104 PIT tagged cutthroat trout immigrated into Auke Lake in the fall of 2001 (Lum and Taylor 2004). Fifty of those fish emigrated from the lake in the spring of 2002, leaving 54 that either chose to remain in Auke Lake or died over the winter. One of the 54 fish was caught while sampling the lake in 2002. We estimate that minimum overwinter survival of these fish was 49%, assuming all fish that stayed in the lake (except for one recaptured) died.

Similar estimated overwinter survival rates for PIT tagged fall immigrants were 67% in 1997–98, 58% in 1998–99, 60% in 1999–2000, and 74% in 2000–2001 (Lum et al. 1999; 2001; Lum and Taylor 2004). The average overwinter survival of PIT tagged sea-run migrants was 62% in Auke Lake. The overwinter survival estimates are higher than the annual survival rate estimates from the full JS model (Table 10) because the later include summer (and perhaps spawning) mortality, and bias those results from pooling the data across trips.

Survival estimates for two similar lake-bound populations in Southeast Alaska (Neck Lake at 51%, SE = 6%, and Florence Lake at 40–52%, SE = 2-3%) are higher than our estimates for Auke Lake

Table 11.–Length composition and estimated abundance at length for cutthroat trout ≥180 mm FL in Auke Lake in 2002. Number sampled (n_k), proportion ($\hat{p}_k$), abundance ($\hat{N}_k$), and standard error ($S\hat{E}$) are shown for each 20-mm length class.

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	57	0.221	0.009	64	4.9
201-220	41	0.159	0.008	46	3.8
221-240	45	0.174	0.008	51	4.0
241-260	54	0.209	0.009	61	4.7
261-280	27	0.105	0.006	30	2.7
281-300	19	0.074	0.005	21	2.1
301-320	7	0.027	0.003	8	1.1
321-340	5	0.019	0.003	6	0.9
341-360	2	0.008	0.002	2	0.6
361-380	1	0.004	0.001	1	0.4
Total	258		$\hat{N}$ =	291	

(Harding et al. 1999, and Rosenkranz et al. 1999). This difference may be the result of immature anadromous fish in Auke Lake that emigrate and do not return. In fact, a JS analysis of the capture history data for 1998–2001 (Lum and Taylor 2004), which excludes all fish observed at the weir, yields an annual survival estimate of 0.51 (SE = 0.065), similar to that found in other studies in Southeast Alaska. The data from this study has been electronically archived by ADF&G, Research and Technical Services in Anchorage, Alaska (Appendix A7).

DISCUSSION AND RECOMMENDATIONS

The Dolly Varden and cutthroat trout assessments in Auke Lake/Creek provide a rare time series of abundance, survival, growth, migration timing, and other life history information for both the resident and anadromous species using Auke Lake. The continuity of these data sets has become increasingly important as urban development continues in the Juneau area.

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 Dredge Lakes, Jordan Creek, and Duck Creek (Lum and Glynn *In prep)*, and at Dredge Creek (*unpublished data*). Cutthroat trout PIT tagged leaving Auke Lake immigrate into these systems, overwinter for up to two years, and then emigrate in the spring. The occurrence of alternative life history or overwinter strategies has potential to affect survival and growth of migrating trout.

Survival estimates generated from this work are either annual survival estimates provided by a Jolly Seber model or overwinter survival estimates obtained from a comparison of tagged fall immigrants to tagged emigrants seen the following spring. The occurrence of an alternative life history or overwinter strategy would only have a minor effect on the overwinter estimate because previous tagging years have shown that only a small number of fish stay in Auke Lake for more than one year. Fish that remain in Auke Lake or in other systems for any length of time

will appear as mortalities unless caught in the multi-year study that allows for alternative capture histories when estimating annual survival, which is updated each year. The more complex life history issue is the percentage of fish in the spring that return in the same year they were tagged. From unpublished data in 1997 and 1998 when PIT tagging was in its infancy at the Auke Creek weir, preliminary estimates suggests that around 30 to 40% of the tagged fish return in the fall to Auke Creek in the same year they were tagged. The accounting of weir emigrants provides a conservative estimate of marine survival within the same year, but would not truly give an accurate accounting without multi-year monitoring.

The comparison of spring emigrants to fall immigrants has provided a chance to look at marine residence and growth. These comparisons have shown that marine growth is inversely related to length at emigration as shown in Figure 12. Marine residence is defined as the time between emigration and immigration through the weir in the same year. When looking at migration timing with respect to marine residence and growth, some interesting patterns emerge. Figures 13 and 14 indicate four fish in the sample left the system early, but returned later in the fall than other early-migrating fish. Three of these fish left the system at lengths ranging from 295 to 310 mm and had growth rates from 0.18 to 0.26 mm/day. The fourth, and smallest (237 mm), fish had the greatest growth rate (0.44 mm/day). Thus, the majority of these fish had slower growth rates and may represent fish that traveled to different streams or were at a life history stage that required more energy, i.e., spawners. Additional studies focused on the recapture of tagged cutthroat trout, supported by the emigrant tagging at the weir and tagging at Auke Lake, would help us better understand migratory behaviors, distribution, life history, and the importance of these migratory populations to Juneau roadside fisheries.

The temporal timing of the lake sampling in 2002 and again in 2003 (in early June) appears to be near ideal as the emigration is complete, water temperatures remain low, and catches are good. This window of opportunity will vary from year to year and may require minor changes to maintain the target sampling conditions. Future analyses can drop the trip-by-trip analysis as it no longer contributes to this study.

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), and their progeny reside (rear) in the lake or its tributaries prior to their spawning migrations. Fall immigrants overwintering in Auke Lake have the option to either emigrate in the spring to spawn elsewhere or to stay in Auke Lake long enough to spawn in the system and then leave during the spring emigration. 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 sample *i* have been *more* likely to be recaptured 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 10) would be biased low by about 12% (or 8% in 2002). Survival estimates should suffer less from the heterogeneity (Pollock et al. 1990); they may be biased low by 8% using the comparison above (or about -1% in 2001). Again, we are not confident in applying the generalized JS model to these data. One apparent conclusion from the generalized model, however, is that fish first captured *prior* to the most recent sampling “survive” at a lower (almost one-half the) rate of newly captured fish. The relatively poor “survival” of the older capture group may result from permanent emigration of the anadromous smolt, and age dependant mortality.

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APPENDIX A

Appendix A1.–Daily water temperature and number of spring emigrants at Auke Creek in 2003.

Date	Water temperature	Pink Salmon Fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead trout
March								
1	2.0							
2	2.1							
3	2.1							
4	2.1	856	0	0	32	0	0	0
5	2.2	1140	0	0	62	1	0	0
6	2.2	565	0	0	45	0	0	0
7	2.2	702	0	0	68	0	0	0
8	2.3	776	0	0	63	0	0	0
9	2.2	850	0	0	39	0	0	0
10	2.3	1013	0	0	66	0	0	0
11	2.2	670	0	0	65	0	0	0
12	2.1	848	0	0	83	0	0	0
13	2.4	493	0	0	44	0	0	0
14	2.5	649	0	0	58	0	0	0
15	2.3	762	0	0	61	0	0	0
16	2.2	2010	0	0	103	0	0	0
17	2.2	757	0	0	76	0	0	0
18	2.1	1238	0	0	104	0	0	0
19	2.4	1778	0	0	90	0	0	0
20	2.4	709	0	0	80	0	0	0
21	2.8	1613	0	0	117	0	0	0
22	2.8	1106	0	0	91	0	0	0
23	2.9	2122	0	0	61	0	0	0
24	2.8	1411	0	0	100	0	0	0
25	2.9	1917	0	0	120	0	0	0
26	3.2	1618	0	0	119	0	0	0
27	3.3	1755	0	0	125	0	0	0
28	3.3	2257	0	0	180	1	0	0
29	3.2	2701	0	0	166	1	0	0
30	3.0	3010	0	0	198	0	0	0
31	3.1	2925	0	0	149	1	0	0
April								
1	2.9	2915	0	0	82	4	0	0
2	2.8	2360	0	0	99	2	1	0
3	2.9	2538	0	0	98	4	0	0
4	3.0	2655	0	0	128	3	0	0
5	3.5	3403	0	0	170	1	0	0
6	3.4	2629	0	0	207	1	1	0
7	3.5	1937	0	0	148	0	1	0
8	3.6	4060	0	0	193	0	2	0
9	3.6	4494	0	0	208	0	0	0
10	3.7	3316	0	0	166	1	0	0
11	3.9	3794	0	0	152	3	0	0
12	3.9	3057	0	0	149	6	1	0
13	3.9	3676	0	0	140	5	0	0
14	4.3	3899	0	0	237	14	0	0
15	4.7	2632	0	0	121	6	1	0
16	4.9	1915	0	0	101	26	3	0
17	4.8	1834	0	0	71	21	2	0
18	4.8	957	0	0	63	17	4	0
19	4.4	693	0	0	29	1	0	0
20	4.4	811	0	0	37	1	0	0

-continued-

Date	Water temperature	Pink Salmon fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead trout
April								
21	5.3	2,064	0	1	39	19	3	0
22	5.6	693	1	0	50	3	2	0
23	6.7	171	0	0	34	59	12	0
24	8.0	152	0	1	14	167	11	0
25	9.7	91	0	2	12	199	10	0
26	10.2	36	0	9	8	245	10	0
27	10.2	32	0	12	0	230	8	0
28	9.4	21	1	45	6	211	13	0
29	10.3	13	0	39	4	239	8	0
30	10.5	22	1	49	10	266	3	0
May								
1	12.0	4	3	81	3	271	4	0
2	10.9	2	9	182	6	449	6	0
3	10.8	1	6	159	3	195	2	0
4	9.9	0	12	153	1	215	3	0
5	9.7	0	10	102	3	38	1	0
6	10.3	0	28	478	0	47	0	0
7	10.0	0	35	450	0	88	0	0
8	10.4	0	63	641	0	112	0	0
9	11.2	2	77	1,124	2	172	2	0
10	12.6	0	87	1,218	2	200	5	0
11	12.1	0	173	1,447	3	393	20	1
12	11.2	1	79	249	4	64	7	0
13	10.6	0	252	468	2	237	9	0
14	10.1	0	354	350	0	122	3	0
15	9.9	0	148	464	0	99	13	2
16	10.2	0	176	912	0	47	4	0
17	10.7	0	155	812	0	85	6	0
18	11.1	1	159	429	1	70	2	0
19	11.8	0	112	950	1	65	4	0
20	12.5	0	86	496	0	39	3	0
21	13.6	0	231	880	0	87	11	0
22	13.8	0	118	707	1	32	8	0
23	13.8	0	137	563	0	26	4	1
24	13.2	0	76	362	0	11	0	0
25	12.7	0	97	262	0	10	2	0
26	11.9	0	48	283	0	15	4	0
27	12.4	0	115	1,253	0	13	4	0
28	12.8	0	50	2,170	0	23	2	0
29	13.0	0	20	602	0	10	1	0
30	13.4	0	83	292	0	16	3	0
31	13.2	0	136	360	0	17	6	0
June								
1	13.7	0	69	404	0	14	0	0
2	13.9	0	73	148	0	7	7	0
3	14.0	0	100	312	0	0	2	0
4	14.1	0	55	216	0	4	1	0
5	14.9	0	24	111	0	2	0	0
6	15.5	0	7	39	0	2	4	0
7	15.8	0	24	86	0	0	0	0
8	15.3	0	14	106	0	0	1	0
9	15.7	0	8	55	0	0	0	0
10	16.4	0	13	90	0	1	0	0
11	16.3	0	4	52	0	0	0	0
12	16.4	0	6	34	0	1	0	0
13	16.6	0	3	12	0	0	0	0

-continued-

Appendix A1.–Page 3 of 3.

Date	Water temperature	Pink Salmon fry	Coho Salmon smolts	Sockeye Salmon smolts	Chum Salmon fry	Dolly Varden	Cutthroat trout	Steelhead trout
June								
14	16.4	0	7	43	0	0	0	0
15	15.9	0	6	38	0	0	0	0
16	15.5	0	5	44	0	0	0	0
17	16.4	0	2	22	0	0	0	0
18	16.0	0	1	21	0	0	1	0
19	15.1	0	7	49	0	3	2	0
20	14.6	0	3	58	0	2	0	0
21	14.9	0	2	61	0	1	0	0
22	15.2	0	1	38	0	3	0	0
23	15.5	0	0	20	0	0	0	0
24	14.9	0	1	21	0	0	1	0
25	14.9	0	0	2	0	0	0	0
26	14.3	0	1	7	0	0	0	0
27	14.0	0	0	3	0	1	0	0
28	14.5	0	0	0	0	0	0	0
29	14.9	0	0	3	0	0	0	0
30	15.7	0	0	2	0	0	0	0
Totals		95,132	3,574	21,154	5,373	5,067	254	4

Appendix A2.–Daily water temperature and number of fall immigrants at Auke Creek weir in 2003. Counts do not include sockeye or coho jacks (0-ocean; < 400 mm MEF).

Date	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead trout
June									
20	14.6	29	0	0	0	0	0	0	0
21	14.9	9	0	0	0	0	0	0	0
22	15.2	0	0	0	0	0	0	0	0
23	15.5	0	0	0	0	0	0	0	0
24	14.9	0	0	0	0	0	0	0	0
25	14.9	0	0	0	0	0	0	0	0
26	14.3	0	0	0	0	0	0	0	0
27	14.0	0	0	0	0	0	0	0	0
28	14.5	0	0	0	0	0	0	0	0
29	14.9	0	0	0	0	0	0	0	0
30	15.7	0	0	0	0	0	0	0	0
July									
1	16.1	0	0	0	0	0	0	0	0
2	16.0	2	0	0	0	0	15	0	0
3	16.0	0	0	0	0	0	6	0	0
4	15.7	96	0	0	0	0	5	0	0
5	15.5	137	0	0	0	0	17	0	0
6	15.6	75	0	0	0	0	5	0	0
7	15.6	25	0	0	0	0	14	0	0
8	16.8	1	0	0	0	0	4	0	0
9	17.9	0	0	0	0	0	0	0	0
10	18.3	0	0	0	0	0	0	0	0
11	19.3	0	0	0	0	0	0	0	0
12	19.3	0	0	0	0	0	0	0	0
13	19.0	0	0	0	0	0	0	0	0
14	18.4	0	0	0	0	0	0	0	0
15	18.0	0	0	0	0	0	0	0	0
16	17.3	0	0	0	0	0	0	0	0
17	16.2	0	0	0	0	0	0	0	0
18	16.0	0	0	0	0	0	0	0	0
19	16.0	0	0	0	0	0	0	0	0
20	15.5	0	0	0	0	0	0	0	0
21	14.7	0	0	0	0	0	0	0	0
22	14.2	0	0	0	0	0	0	0	0
23	14.0	0	0	0	0	0	0	0	0
24	14.6	0	0	0	0	0	0	0	0
25	14.1	0	0	0	0	0	0	0	0
26	13.7	0	0	0	0	0	0	0	0
27	15.3	1,936	9	66	0	0	123	0	0
28	15.9	488	38	165	0	8	204	0	0
29	15.0	171	63	222	0	1	190	0	0
30	15.6	83	102	104	0	1	187	0	0
31	16.0	23	74	91	0	6	75	0	0
Aug.									
1	15.9	11	28	91	0	2	43	0	0
2	15.8	11	37	72	0	2	67	0	0

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Appendix A2.–Page 2 of 3.

Date	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead trout
Aug									
3	15.7	8	20	93	0	2	86	0	0
4	15.6	4	36	85	0	0	61	0	0
5	15.3	3	18	71	0	1	46	0	0
6	16.2	3	22	48	0	1	23	0	0
7	16.6	5	25	51	0	1	31	0	0
8	17.1	4	17	25	0	1	15	0	0
9	17.3	2	11	28	0	0	18	0	0
10	17.5	0	41	18	0	0	9	0	0
11	17.5	5	65	27	0	0	40	0	0
12	18.0	2	39	29	0	0	30	0	0
13	17.8	0	36	28	0	0	8	0	0
14	16.8	2	53	22	0	0	6	0	0
15	16.7	2	95	24	0	0	22	0	0
16	15.8	4	83	41	0	0	19	0	0
17	15.5	18	342	58	0	0	68	0	0
18	15.5	18	511	37	0	8	67	0	0
19	15.5	4	187	19	0	7	35	0	0
20	15.0	6	247	12	0	33	33	0	0
21	14.8	13	1,153	8	0	3	43	0	0
22	14.8	3	740	8	0	0	7	0	0
23	15.1	3	252	14	0	10	1	0	0
24	14.9	0	166	8	0	5	3	0	0
25	14.7	0	200	2	0	4	4	0	0
26	14.9	1	248	2	0	4	9	0	0
27	15.2	1	175	1	0	0	27	0	0
28	14.5	0	160	0	0	7	4	0	0
29	14.4	3	243	2	0	7	22	0	0
30	15.0	0	255	0	0	0	13	0	0
31	14.4	3	593	3	1	4	28	0	0
Sept.									
1	13.9	6	534	0	0	12	36	0	0
2	13.4	7	2,062	1	0	7	284	0	0
3	13.2	3	700	0	0	5	137	0	0
4	13.0	2	243	1	0	6	79	0	0
5	13.5	0	87	0	0	2	47	0	0
6	13.7	0	70	0	0	4	20	0	0
7	13.5	0	46	0	0	1	16	0	0
8	12.8	4	249	0	0	5	105	0	0
9	12.4	1	114	0	0	0	293	0	0
10	12.7	1	33	0	31	0	119	7	0
11	12.1	1	9	0	40	1	80	0	0
12	12.2	0	17	0	44	1	135	0	0
13	12.1	0	8	0	22	0	36	0	0
14	11.4	0	14	0	14	0	100	0	0
15	11.1	0	5	0	49	0	35	0	0
16	10.8	0	1	0	37	0	97	7	0
17	10.8	0	0	0	8	0	79	7	0
18	10.4	0	0	0	1	0	66	5	0

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Appendix A2.–Page 3 of 3.

Date	Water temperature	Sockeye Salmon adults	Pink Salmon adults	Chum Salmon adults	Coho Salmon adults	Chinook Salmon adults	Dolly Varden	Cutthroat trout	Steelhead trout
Sept.									
19	10.4	0	1	0	3	0	26	9	0
20	10.3	0	1	0	2	0	1	2	0
21	10.2	0	1	0	9	0	24	0	0
22	9.9	0	1	0	6	0	8	4	0
23	10.2	0	0	0	21	0	22	7	0
24	9.9	0	0	0	11	0	8	9	0
25	9.6	0	0	0	65	0	35	6	0
26	9.7	0	0	0	49	0	67	11	0
27	9.7	0	0	0	12	0	10	5	0
28	9.8	0	0	0	44	0	11	2	0
29	9.8	0	0	1	40	0	54	9	0
30	10.0	0	0	0	11	0	7	1	0
Oct.									
1	10.2	0	0	0	4	0	4	1	0
2	10.2	0	0	0	6	0	2	1	0
3	10.2	0	0	0	4	0	17	8	0
4	10.2	0	0	0	9	0	9	2	0
5	10.2	0	0	0	5	0	1	0	0
6	10.1	0	0	0	5	0	6	3	0
7	10.1	0	0	0	10	0	4	2	0
8	9.7	0	0	0	9	0	17	2	0
9	9.7	0	0	0	3	0	11	1	0
10	9.5	0	0	0	1	0	19	2	0
11	9.1	0	0	0	0	0	7	1	0
12	8.7	0	0	0	0	0	10	1	0
13	8.7	0	0	0	2	0	0	0	0
14	8.6	0	0	0	3	0	0	4	0
15	8.1	0	0	0	0	0	1	1	0
16	8.1	0	0	0	0	0	0	0	0
17	7.9	0	0	0	0	0	2	0	0
18	8.0	0	0	0	0	0	0	0	0
19	8.1	0	0	0	0	0	0	0	0
20	7.8	0	0	0	1	0	0	0	0
21	7.6	0	0	0	0	0	0	0	0
22	7.7	0	0	0	0	0	0	0	0
23	7.6	0	0	0	0	0	0	0	0
24	7.5	0	0	0	0	0	0	0	0
25	7.8	0	0	0	0	0	25	0	0
26	7.9	0	0	0	2	0	19	3	0
27	7.9	0	0	0	1	0	34	4	0
28	7.8	0	0	0	0	0	14	1	0
29	7.0	0	0	0	0	0	4	1	0
30	6.5	0	0	0	0	0	2	0	0
31	6.3	0	0	0	0	0	0	0	0
Total		3,239	10,580	1,578	585	162	3,978	129	0

Appendix A3.–Capture histories for Auke Lake Jolly-Seber models, 1998–2003.

Capture history[a]	Frequency	Capture history[a]	Frequency	Capture history[a]	Frequency
Annual model					
000001	271	001110	2	011110	2
000010	117	001111	1	100000	63
000011	84	010000	236	101000	4
000100	152	010010	2	110000	20
000101	2	010100	4	111000	2
000110	28	011000	78		
000111	10	011001	1		
001000	157	011010	5		
001010	7	011011	1		
001100	31	011100	1		
Trip-by-trip model					
0000000001	271	0000111100	1	1000000000	24
0000000010	117	0000111110	2	1000001000	1
0000000011	84	0001000000	63	1000100000	3
0000000100	152	0001000010	1	1001000000	1
0000000101	2	0001000100	1	1001001000	1
0000000110	28	0001001000	9	1001100000	2
0000000111	10	0001010000	4	1010000000	2
0000001000	51	0001011000	1	1010100000	2
0000001010	3	0001100000	67	1100000000	1
0000001100	13	0001100100	1	1101000000	1
0000010000	57	0001101000	6	1110000000	2
0000010010	2	0001101001	1		
0000010100	4	0001101010	1		
0000010111	1	0001110000	10		
0000011000	49	0001111000	13		
0000011010	2	0001111010	1		
0000011100	14	0010000000	9		
0000011110	2	0010100000	1		
0000100000	106	0011000000	1		
0000100010	1	0100000000	23		
0000100100	2	0100001000	2		
0000101000	18	0100010000	1		
0000101010	2	0100100000	3		
0000101011	1	0101000000	3		
0000110000	7	0101001000	1		
0000110010	1	0101100000	3		
0000111000	10	0110000000	2		

[a] A "0" signifies not captured during that particular sampling event while a "1" signifies a capture; i.e., a capture history of 1,1,1,0 represents a group of fish that were captured during the 1^{st}, 2^{nd}, and 3^{rd} sampling events and not captured during the 4^{th} event. The sampling events for the trip-by-trip model correspond to trips completed within a year, in this case: 1998(1), 1998(2), 1998(3), 1999(1), 1999(2), 2000(1), 2000(2), 2001(1), 2002(1), and 2003(1), with () indicating the number of trips completed within the year. The sampling events for the annual model correspond to the sample year.

Appendix A4.–Number of cutthroat trout marked in 2002 and recaptured in 2003 by stratum, and chi-square test for mixing between years.

Stratum fish was marked	Total fish marked in 2002	Numbers recaptured in 2003 by stratum A[a]	B[b]	C[c]	Total (all strata)	Number not seen	Proportion recaptured
A	61	6	7	2	15	46	0.25
B	109	5	15	13	33	76	0.30
C	88	6	4	16	26	62	0.30
Total	258	17	26	31	74	184	0.29
Unmarked fish caught		74	110	113	297		
Total caught in recapture event		91	136	144	371		
Marked fraction		0.19	0.19	0.22	0.20		

$\boldsymbol{X^2}$ = 0.67, 2 df, P = 0.72, *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 (year-by-year model) 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	40.00
Captured in 2001 and not recaptured in 2002		36.00	152.00
χ^2 = 1.618, 1 df, P = 0.203	$\hat{p} \rightarrow$	0.122	0.208

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 = 0.003	$\hat{p} \rightarrow$	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	84.00
Captured in 2002 and not recaptured in 2003		46.00	117.00
χ^2 = 8.592, 1 df, P = 0.003	$\hat{p} \rightarrow$	0.207	0.418

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	2.00
χ^2 = 0.319, 2 df, P = 0.852	$\hat{p} \rightarrow$	0.938	1.00	0.950

Appendix A6.–Summary of capture probabilities by tag group and sampling trip for the Jolly-Seber experiments 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
Annual model					
1998 (1-3)	-	-	-	-	-
1999 (1,2)	0.091	0.285	-	-	-
2000 (1,2)	0.106	0.207	1.000	1.000	0.936
2001 (1)	0.122	0.208	0.669	0.300	0.829
2002 (1)	0.207	0.418	0.938	1.000	0.950
2003 (1)	-	-	-	-	-
Mean	0.132	0.280	0.869	0.767	0.905
Trip-by-trip model					
1998 (1)	-	-	-	-	-
1998 (2)	0.750	0.395	-	-	-
1998 (3)	0.250	0.182	0.333	0.667	0.133
1999 (1)	0.538	0.648	0.545	0.000	0.500
1999 (2)	0.289	0.298	0.692	0.714	0.862
2000 (1)	0.569	0.565	0.273	0.727	0.467
2000 (2)	0.196	0.239	0.878	0.966	0.905
2001 (1)	0.122	0.208	0.643	0.704	0.813
2002 (1)	0.207	0.418	0.938	1.000	0.950
2003 (1)	-	-	-	-	-
Mean	0.365	0.369	0.615	0.682	0.661

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

Data File	Description
Down2003.xls	Excel file of the counts of emigrant salmonids at Auke Creek weir, 2003.
DV2003.xls	Excel file of the lengths of marked and unmarked Dolly Varden emigrating at Auke Creek weir, 2003.
spct03.xls	Excel file of recovered tagged cutthroat trout with lengths and growth information for the 2003 field season.
Lake 2003.xls	Excel file of cutthroat trout PIT tagging information for the abundance study in Auke Lake, 2003.
Up2003.xls	Excel file of the counts of immigrant salmonids at Auke Creek weir, 2003.