Fishery Data Series No. 10-82

Abundance of Cutthroat Trout in Auke Lake, Southeast Alaska, in 2005 and 2006

by

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December 2010

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

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

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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-10-20 and F-10-21, Job No. R-1-2.

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

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This document should be cited as:
Harding, R. D, C. L. Hoover, and R. P. Marshall. 2010. Abundance of cutthroat trout in Auke Lake, Southeast Alaska, in 2005 and 2006. Alaska Department of Fish and Game, Fishery Data Series No. 10-82, Anchorage.

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ABSTRACT

The estimated abundance of cutthroat trout ≥180 mm FL in Auke Lake, located near Juneau, Alaska, was 255 (SE = 65) in spring 2005 and 454 (SE = 101) in spring 2006; these estimates fall between the estimates made in previous years. Estimated annual survival of this mixed population of resident and anadromous fish between 2004 and 2005 was 0.268 (SE = 0.072), and overwinter mortality of tagged, mature anadromous adults was 67%. Average length of cutthroat trout in 2006 was 244 mm FL (SE =4).

Key words: Southeast Alaska, Auke Lake, Auke Creek, cutthroat trout, sea-run, abundance, length, passive integrated transponder (PIT), Jolly-Seber model, Petersen model, overwinter survival

INTRODUCTION

The Auke Lake system, north of Juneau, Alaska, has native populations of Dolly Varden *Salvelinus malma;* cutthroat trout *Oncorhynchus clarkia, and* pink *O. gorbuscha*, chum *O. keta*, sockeye *O. nerka*, and coho salmon *O. kisutch*. There is also a small number of juvenile steelhead (*O. mykiss)* that are thought to immigrate into Auke Lake during late fall and overwinter in the lake; no spawning population of steelhead or rainbow trout have been observed in Auke Lake.

The cutthroat trout in Auke Lake exhibit a combination of both resident and sea-run life history forms. The resident form of cutthroat trout utilize the Auke Lake for several years before maturing and migrating into inlet streams to spawn; these fish may never leave the Auke Lake system. Sea-run cutthroat trout may spend several years as resident forms in Auke Lake before emigrating to saltwater as smolts, and then returning several months later to Auke Lake or another freshwater body to overwinter. Auke Lake is also a known site for overwintering adult cutthroat trout that leave in early spring and migrate to nearby streams to spawn. These sea-run forms may remain in nearby freshwater streams or along nearshore areas in salt water before returning to Auke Lake to overwinter. These life history patterns or cycles may be repeated one or more times (Northcote 1997; Trotter 1997), or fish may adopt a complex combination between resident and sea-run forms (Taylor 2007).

Auke lake was identified through a strategic planning process by the Alaska Department of Fish and Game (ADF&G) in 1989 as an important sport fishing opportunity along the Juneau roadside (Schwan 1990). One of the goals of this strategic plan was to improve the cutthroat trout fishery in Auke Lake to help satisfy the demand for sport fisheries along the Juneau roadside. Sport anglers continue to target cutthroat trout in Auke Lake through the ice during the winter and from the beach or boats along the lake and nearshore marine areas during the remainder of the year (Table 1).

There have been several efforts to supplement the wild cutthroat trout population in the Auke system by staff from ADF&G and National Marine Fisheries Service (NMFS) as well as volunteers from the local Trout Unlimited chapter. Gametes were collected at the weir from mature emigrants, fertilized, and incubated at the Auke weir facility 6 times between 1981 and 1993 (Taylor and Lum 2006). Progeny from these fish were subsequently fin clipped and released into Auke Lake. The total number of hatchery-reared cutthroat trout released into Auke Lake during this time was just over 16,000, averaged about 2,700 each stocking, and ranged from 1,286 in 1981 to just over 4,000 in 1982 (Lum et al. 1999). Hatchery-origin cutthroat trout emigrants, as identified by fin clips, were counted through the Auke Creek weir between 1983 and 2000 and ranged from 691 emigrants in 1987 to just 1 fish during 2000. Of the nearly 2,000 total hatchery-origin cutthroat trout emigrants during this time, approximately 63% emigrated during 1987-1989 (Taylor and Lum 2005). The peak emigrant count between 1980 and 2006 of wild cutthroat trout occurred between 1994 and 1997 when annual counts exceeded 400. It is difficult to evaluate any long-term effect the hatchery-reared cutthroat trout may have had by either contributing to the wild emigrant counts, or the abundance of cutthroat trout in Auke Lake because there was no initial abundance information in Auke Lake prior to stocking. Evaluation of the stocking is further complicated as only fin clips were used to identify hatchery-origin fish instead of unique tags.

A weir has been operated on Auke Creek, the outlet stream of Auke Lake, since 1962 (e.g., Taylor and Lum 1999-2006; Hoover 2007, 2008; Echave 2009; Taylor 2006, 2007). A permanent structure was constructed in 1980 and additional modifications were made in 1997 to capture all immigrant Dolly Varden and cutthroat trout. The number of wild cutthroat trout emigrating from Auke Creek generally increased from 1983 through 1996, at which point the number of emigrants began to significantly decline (Harding et al. 2006). The low number of emigrants in the early to mid 1980s may have been caused by overharvest in the sport fishery (S. G. Taylor, NMFS, personal communication), but the only harvest estimated by the Statewide Harvest Survey was 112 in 1986. The cause of the more recent decline is unknown but the impacts of urbanization (Shaul et al. 2003) and environmental changes (e.g., warm water temperatures, Taylor 2007) are potential factors.

Studies at Auke Lake and Auke Creek weir have provided important insights into life history, behavior, age composition, maturity, migration, run timing, and growth of fish present in the Auke Lake system. A radio telemetry study of emigrant cutthroat trout was conducted in 1994 and tagged fish were tracked into 10 streams along the Juneau roadside (Jones and Seifert 1997) This study documented the importance of Auke Lake cutthroat trout to other Juneau roadside streams.

The time series of Auke weir emigrant counts is the longest continual record for coastal cutthroat trout throughout their native range. Additionally data collected at Auke weir and lake have been presented to the Alaska Board of Fisheries (Harding et al. 2006).

Cutthroat trout emigrants from Auke Lake were first tagged with uniquely numbered visual implant (VI) tags in 1994. Passive integrated transponder (PIT) tags replaced VI tags at the weir in 1997. Anglers in marine waters voluntarily reported catching Auke Lake emigrants (identified by missing adipose fin) during spring 1997 and over the next few summers. This information reinforced the importance of Auke Lake emigrants to Juneau roadside fisheries (Table 2) and the role that Auke Lake plays for sea-run cutthroat that overwinter or reside in Auke Lake.

A pilot study was conducted in 1997 to evaluate the feasibility of capturing enough cutthroat trout in Auke Lake to successfully estimate the abundance of fish ≥180 mm FL. Although catch rates were low, it was believed that adequate sample sizes could be obtained and a mark-recapture program to estimate the annual abundance of "summer-resident" trout (i. e., post emigration) began in 1998, and continued annually through 2006 (Lum et al. 1998-2002; Lum and Taylor 2004, 2006, 2006a-b). The methodology used in this study (i.e., count emigrants through a weir followed by estimating the abundance of fish remaining in the lake) was proven to be effective in providing robust analysis of population size after sea-run fish were absent from the lake in the Sitkoh (Brookover et al. 1999) and Lake Eva (Schmidt et al. 1998) watersheds.

OBJECTIVES

The study objectives for 2006 were to:

1. estimate abundance of cutthroat trout ≥180 mm FL in 2005;
2. estimate survival and recruitment rates of cutthroat trout ≥180 mm FL between 2005 and 2006;
3. estimate abundance of cutthroat trout ≥180 mm FL in 2006.

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 5 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, along with portions of the stream banks in inlet streams.

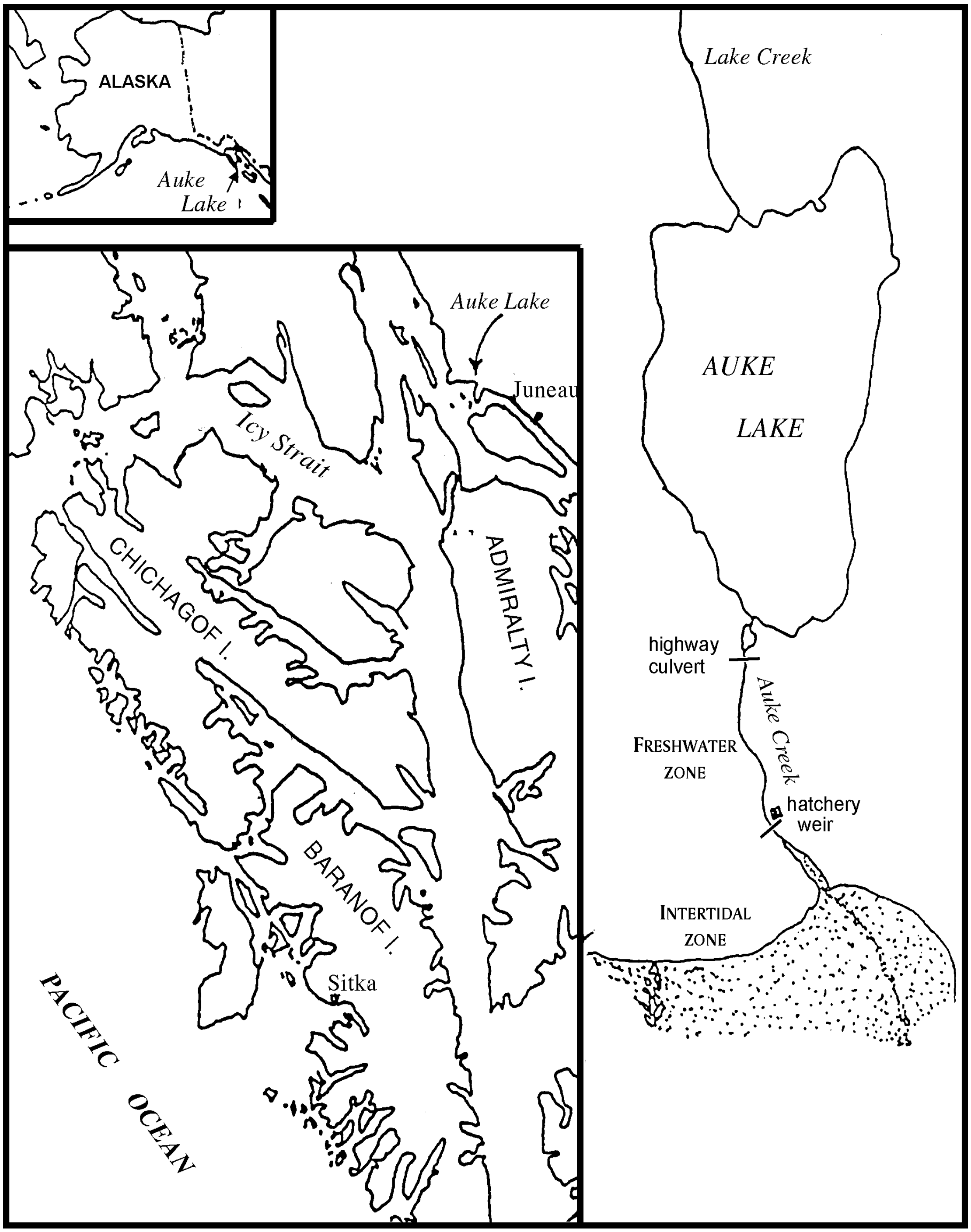

Figure 1.–The Auke Lake system in northern Southeast Alaska and location of the Auke Creek weir.

Table 1.–Estimates of sport fishing effort, total catch, and harvest of cutthroat trout in the Auke Creek drainage, 1996–2006. 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).

					Cutthroat trout	
Year	**Anglers**	**Trips**	**Days**	**Responses**	**Catch**	**Harvest**
1996	40	397	375	3	1,104	0
1997	45	47	47	2	16	0
1998	46	100	113	4	101	17
1999	33	12	33	1	9	0
2000	54	22	54	2	195	0
2001	86	307	353	5	807	24
2002	135	788	1,071	8	1,735	38
2003	17	25	25	1	56	0
2004	83	14	83	1	0	0
2005	53	14	88	2	524	40
2006	89	125	134	8	176	0

Table 2.–Estimates of sport fishing effort, total catch, and harvest of cutthroat trout and Dolly Varden in the marine areas surrounding Auke Creek, 1996–2006. Included in the counts are boat and shore fishing in Auke Bay and boat and shore fishing near the mouth of Auke Creek.

					Cutthroat trout	
Year	**Anglers**	**Trips**	**Days**	**Responses**	**Catch**	**Harvest**
1996	1,989	2,313	2,926	364	58	11
1997	1,577	2,142	2,944	260	28	0
1998	1,735	2,088	2,797	296	15	15
1999	1,847	2,445	3,885	324	67	29
2000	2,770	3,575	5,588	520	45	9
2001	2,429	3,916	4,841	460	12	0
2002	1,672	2,036	2,927	336	7	7
2003	2,122	2,037	3,419	300	0	0
2004	1,707	2,081	3,406	256	21	0
2005	1,894	2,896	4,401	250	0	0
2006	1,574	1,304	2,156	226	0	0

METHODS

CAPTURE, TAGGING AND RECOVERY

Sampling in Auke Lake began with 3 trips in July and August of 1998, then were reduced to 1 or 2 trips/yr (Table 3). As sampling moved to earlier dates in 1999, and especially in 2001, emigrations of anadromous trout were incomplete before sampling began. In 2002 through 2006, sampling was delayed until June to estimate abundance after the anadromous emigration, yet still prior to the onset of high water temperatures that can occur in the summer. Cutthroat trout were captured in 2006 using traps baited with Chinook salmon eggs. The 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). Trap soak times were typically 22 to 24 hours.

Table 3.–Summary of the dates of Auke Lake sampling, 1998–2006.

Year	Trip	Sampling dates
1998	1	July 8 to 17
	2	July 22 to 31
	3	August 5 to 14
1999	1	May 22 to June 2
	2	June 7 to 16
2000	1	May 2 to 11
	2	May 16 to 25
2001	1	April 16 to 25
2002	1	June 4 to 13
2003	1	June 4 to 13
2004	1	June 7 to 16
2005	1	May 31 to June 9
2006	1	June 1 to 6
	2	June 13 to 18

Only cutthroat trout ≥180 mm FL were included in this abundance experiment because fish <180 mm FL are not believed to be fully recruited by our gear. Furthermore, by following the standardization established in numerous other studies of estimating abundance of trout ≥180 mm FL, comparison between studies is possible.

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. During the first trip in 2006, unmarked cutthroat trout ≥180 mm FL were tagged with a uniquely numbered PIT tag and given an adipose fin clip. During the second 2006 sampling trip, unmarked cutthroat trout ≥180 mm FL were only marked with a shallow upper caudal clip and unmarked cutthroat trout <180 mm FL were only marked with a shallow lower caudal clip.

Fish caught more than once during a sampling event 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 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 4). The depth, sampling area, and number of fish caught were recorded by trap set.

ABUNDANCE IN 2005

A "full" Jolly Seber (JS) model was used to estimate abundance in 2005, and survival, and recruitment between 2004 and 2005. Data were pooled by sampling year (1998-2006) 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, then input to 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.

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, 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 3 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.

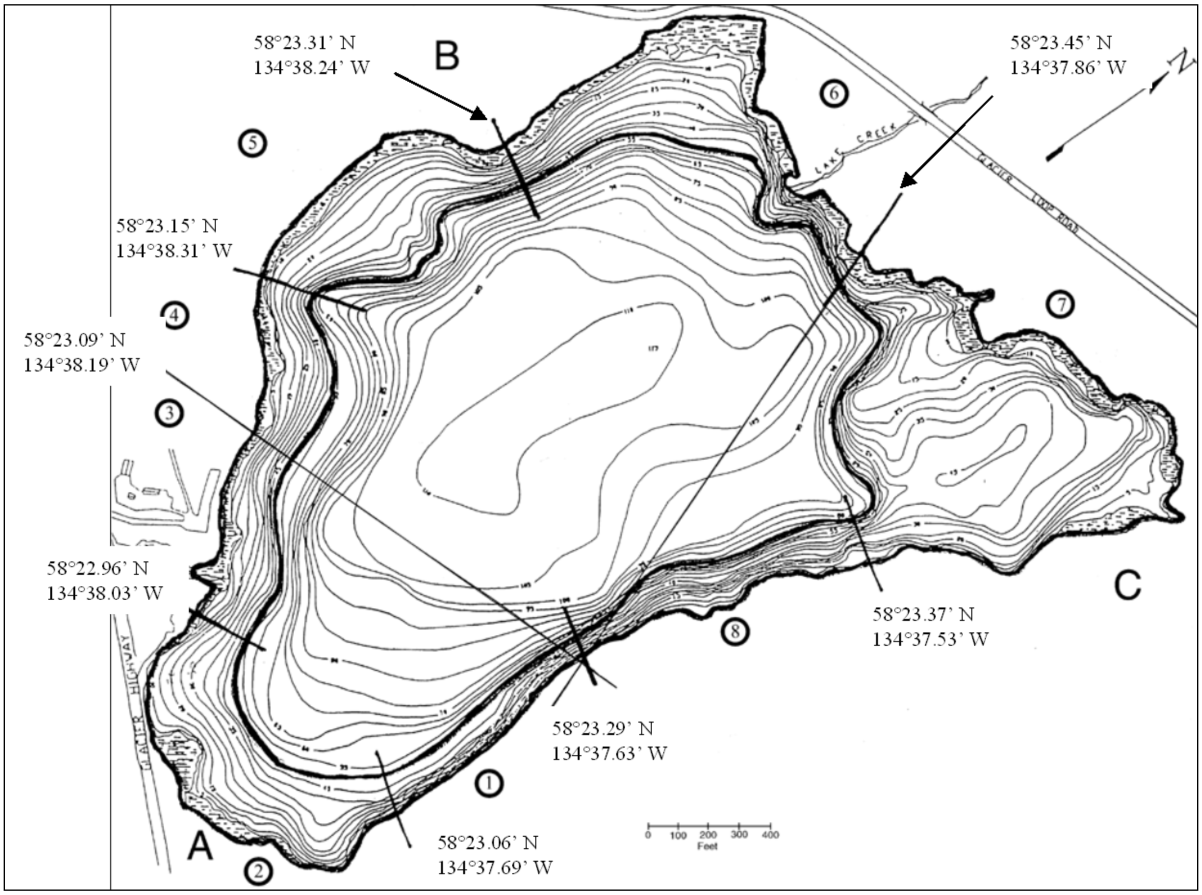

Figure 2.–Bathymetric map of Auke Lake showing location of sampling areas in 2006. The lake area inside the inner bold line denotes depths >15 m that are excluded from sampling. The 2 intersecting straight lines indicate the separation between the 3 strata (A, B, and C) used in analysis.

Table 4.–Distribution of sampling effort in Auke Lake by area in 2006. Sampling effort was uniformly distributed across each of the 8 areas (Figure 2) of the lake in direct proportion to the amount of lake surface (≤15m depth) present, given a goal of deploying 192 traps over the two 6-day sampling trips.

Area No.	Analysis stratum	Area (km^2)	Proportion [a]	No. of traps set each day	Total trap effort (sets)
1	A	0.5463	0.0459	1	12
2	A	2.6098	0.2195	4	48
3	A	1.0583	0.0890	1	12
4	B	0.8275	0.0696	1	12
5	B	1.4691	0.1236	2	24
6	B	1.4562	0.1225	2	24
7	C	3.1297	0.2632	4	48
8	C	0.7932	0.0667	1	12
Totals		11.8901	1.0000	16	192

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

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 2006c).

The equal probability of capture assumption can also be violated if sampling is size selective. While this was not directly tested in 2006, considerable experience with the sampling gear used at Auke Lake shows that it typically is unselective for fish ≥180 mm FL.

The assumption that all fish have the same chance of surviving from the i^{th} to the $(i+1)^{th}$ sample implies the absence of significant age- or size-dependent mortality rates. The experimental design could not test for this, but note that permanent emigration of some smolt, and age-dependent mortality do likely occur in the population (Lum and Taylor 2006a, c).

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. Sampling events spanned but 9 days in most years, so significant violations of assumption 5 were not expected. However, the likelihood of significant emigration or mortality during sampling is increased in years when sampling spanned longer periods (Table 3).

ABUNDANCE IN 2006

Two sampling trips were made in 2006 to enable us estimate abundance of cutthroat trout in 2006 using a 2-event closed population (CP) model (Seber 1982). Fish captured several times during a sampling trip were treated as being caught only once.

Assumptions of our CP model include:

1) the population was closed (fish do not enter the population via growth or immigration, or leave via death or emigration during the experiment);
2) all cutthroat trout had a similar probability of capture in the first or second event, or marked and unmarked cutthroat trout mixed completely between events;
3) marking of cutthroat trout in the first event did not affect the probability of capture in the second event;
4) cutthroat trout did not lose marks between events, and marks were recognized and reported during the second event.

The first (closure) assumption was not directly tested; the relatively short span of the experiment (18 days, Table 3) works to minimize the possibility of significant entries into or departures from the population.

The second assumption was evaluated with tests of consistency for a 2-event Petersen CP estimator (Appendix A1) and with a series of Kolmogorov-Smirnov (K-S) tests (Conover 1980) for size-selective sampling (Appendix A2). The consistency tests compare capture and recapture rates in each of three areas of the lake (Figure 2). If the consistency tests reject the Petersen estimator, a stratified estimator (Seber 1982, Arnason et al. 1996) is appropriate. The protocol specified in Appendix A2 provided guidance for conducting K-S tests to evaluate the potential for size-selective sampling as well as the effects of marking on catchability (assumption 3). Experienced technicians and procedures minimized stress on captured fish and negative impacts from handling and tagging (assumption 3).

Assumption 4 was robust in this experiment because all fish had a secondary mark and technicians were instructed to thoroughly examine all captured fish for marks.

Barring need for a stratified CP model, abundance was estimated by using the Chapman modification of the Petersen estimator:

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

where $\hat{N}$ is the estimated abundance of cutthroat trout ≥180 mm FL, n_1 is the number of cutthroat trout ≥180 mm FL marked in the first event, n_2 is the number of cutthroat trout ≥180 mm FL examined in the second event, and m_2 is the number of marked cutthroat trout recaptured in the second event.

The standard error along with a 90% confidence interval about $\hat{N}$ were estimated by using a parametric bootstrap routine, whereby random variates (m_2) were generated from a hypergeometric distribution based upon fixed values of n_1, n_2, and $\hat{N}$. For each of the generated m_2 values (B = 2,000 iterations), equation (1) was used to generate a potential abundance estimate ($\hat{N}_k$). A 90% confidence interval about the mean was calculated using the 5th and 95th percentiles of the bootstrap distribution (Efron and Tibshirani 1993). The variance of $\hat{N}$ was calculated by:

$$\text{var}[\hat{N}] = \sum_{k=1}^{B} (\hat{N}_k - \overline{N})^2 / (B - 1) \qquad (2)$$

Length and Abundance-at-Length

The fraction p_k of cutthroat trout in 20-mm size increments in Auke Lake in 2006 was estimated:

$$\hat{p}_k = \frac{n_k}{n} \qquad (3)$$

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

$$\hat{\text{var}}(\hat{p}_k) = \frac{\hat{p}_k (1 - \hat{p}_k)}{n - 1} \qquad (4)$$

where n is the number of fish measured for length and n_k is the subset of n that belong to length group k. The standard error of p_k was estimated:

$$\hat{SE}(\hat{p}_k) = \sqrt{\hat{\text{var}}(\hat{p}_k)} \qquad (5)$$

The abundance of cutthroat trout by size increment N_k in 2005 and 2006 was estimated:

$$\hat{N}_k = \hat{p}_k(\hat{N}) \qquad (6$$

where estimates of p_k for 2005 are from Lum and Taylor (2006a) and variances of $\hat{N}_k$ were estimated:

$$\hat{\text{var}}[\hat{N}_k] = \hat{\text{var}}(\hat{p}_k)\hat{N}^2 + \hat{\text{var}}(\hat{N})\hat{p}_k^2 - \hat{\text{var}}(\hat{p}k)\hat{\text{var}}(\hat{N}) \qquad (7)$$

The standard error of N_k was estimated:

$$\hat{SE}(\hat{N}_k) = \sqrt{\hat{\text{var}}(\hat{N}_k)} \qquad (8)$$

Size selectivity in sampling in 2006 was investigated according to the protocols in Appendix A2.

RESULTS

Capture, Tagging and Recovery

A total of 212 cutthroat trout between 111 and 379 mm FL were captured from June 1 to June 18, 2006 using large traps (Table 5). The catch per unit of effort (CPUE) in early June was 0.047 fish per hour (Table 5). No tag loss was observed during this experiment. A total of 167 (79%) of the 212 fish were ≥180 mm FL.

Table 5.–Sampling effort (hours), cutthroat trout catch, and catch per unit effort (CPUE, fish per hour) by large traps in Auke Lake in 2006. All captures of a fish are included in the catch.

			≥180 mm		<180 mm		Combined	
Sampling dates	**Gear type**	**Efforts (hours)**	**Catch**	**CPUE**	**Catch**	**CPUE**	**Catch**	**CPUE**
June 1–June 6	Large traps	2,281	84	0.037	24	0.011	108	0.047
June 13–June 18	Large traps	2,166	83	0.038	21	0.010	104	0.048
June 1–June 18	Large traps	4,447	167	0.038	45	0.010	212	0.048

ABUNDANCE IN 2005

Of the 167 cutthroat trout ≥180 mm FL captured in 2006, 27 were captured more than once and were therefore considered "redundant" within the sampling event. The resulting total was 140 unique cutthroat trout ≥180 mm FL. Of these, 18 fish had been tagged in previous years. Capture histories and summary statistics for sampling fish ≥180 mm FL were compiled for the JS analyses (Appendix A3; Table 6).

Table 6.–Summary statistics for Jolly-Seber models, Auke Lake, 1998–2006.

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	100	4
2003	370	99	370	99	5
2004	290	91	290	44	13
2005	134	52	134	13	5
2006	140	18	140	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 > 0.69) between all successive sample years 1999–2005 (Lum and Taylor 2006b) and 2005–2006 (Appendix A4). Mixing was expected across years because Auke Lake is relatively small. The component-1, component-2, and overall GOF tests for homogeneous capture/survival probabilities (Table 7; Appendix A5) suggested the JS model does not fit the data well (P < 0.001). Inspection of the test results (Table 7) shows that less than half (3 of the 7) component-1 GOF statistics were significant at 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 nearly twice that for recapturing fish tagged in previous years. The component-2 GOF tests are less telling (as but 1 of 6 tests are significant at P < 0.05), although these are less powerful tests due to small sample size (Appendix A5).

Table 7.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities by tag group. 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.

	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	10.126	0.002	0.397	0.820*
2003	2.120	0.145	4.183	0.124*
2004	0.081	0.776	5.167	0.076*
2005	0.392	0.532	0.938	0.626*
Overall by component	22.90	0.002	22.34	0.034
Overall:	45.24	< 0.001		

The poor GOF tests suggests 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 versus P = 0.034 for the generalized "Model 2", see Pollock et al. 1990, p.41).

Because the generalized model uses a subset of the available capture histories, precision of those estimates was much lower than the precision of the estimates from the full JS model (Table 8). The 1999 estimate (for example) from the generalized model (808, SE = 428) looks larger than the estimates from the full JS (561, SE = 118) or Petersen (464, SE = 23; Lum et al. 2001) model, 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 in Table 8 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.

Table 8.–Estimates of abundance ($\hat{N}$), survival ($\hat{\phi}$), and recruitment ($\hat{B}$) of cutthroat trout ≥180 mm FL at Auke Lake, 1998–2005. Estimates from POPAN Model 3 (right panel) are simply shown for comparison to the preferred estimates from full JS model.

	Full JS Model						Generalized Model (Model 3 POPAN)					
Year	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{B}$	$SE(\hat{B})$
1998	-	-	0.411	0.088	-	-	-	-	0.592	-	-	-
1999	561	118	0.349	0.045	199	48	808	428	0.381	0.103	142	372
2000	394	44	0.370	0.071	526	120	450	83	0.445	0.170	652	258
2001	672	139	0.218	0.031	154	30	852	321	0.221	0.064	147	68
2002	301	22	0.437	0.041	305	25	336	45	0.439	0.056	304	41
2003	436	30	0.451	0.069	357	61	452	41	0.449	0.087	355	75
2004	554	84	0.268	0.072	107	36	558	105	0.280	0.104	111	50
2005	255	65	-	-	-	-	267	93	-	-	-	-

ABUNDANCE IN 2006

A total of 84 cutthroat trout ≥180 mm FL were captured in the first sampling trip (T1) of 2006 and 83 were captured in the second trip (T2, Table 5). Five of the 84 fish captured in T1 were seen twice in T1, and 10 of the 83 fish captured in T2 were seen twice in T2. Twelve fish seen in T1 were also seen in T2.

Abundance in 2006 was estimated at 454 cutthroat trout ≥180 mm FL (SE = 101; 90% CI = 337 – 694; n_1 = 79, n_2 = 73, m_2 = 12). No tag loss was observed.

Stratification by length appears unnecessary as the K-S tests did not indicate significant differences in length composition between fish marked in the first event and fish recaptured in the second event (D = 0.26, P = 0.46, Figure 3). A second K-S test compared the length composition of fish captured in the first event to those captured in the second event (Figure 4). This test offered evidence of size selectivity in the first event (D = 0.26, P = 0.013), therefore only data from the second sampling event was used to estimate length composition in 2006.

Heterogeneity in capture probabilities due to spatial factors (Appendix A7) was not an apparent source of bias in the abundance estimate as no difference was detected in the marked fractions among the recovery areas (χ^2 = 1.74, df = 2, P = 0.42; the "equal proportions test" in Appendix A1). Also, mixing was also "complete" (χ^2 = 1.08, df = 6, P = 0.58) according to the pooled version of the "complete mixing test" in Appendix A1. Acceptance of either null hypothesis suggested use of the pooled Petersen estimator.

LENGTH AND ABUNDANCE-AT-LENGTH

The average size of cutthroat trout ≥180 mm FL in Auke Lake in 2005 was estimated at 246 mm FL (SE = 4). Fish ranged from 180 to 335 mm FL and samples had a standard deviation of 41 mm FL. Slightly less than half (47%) of the population in 2005 was ≤240 mm FL (Table 9).

The average size of cutthroat trout ≥180 mm FL in Auke Lake in 2006 was estimated at 244 mm FL (SE = 4). Fish ranged from 180 to 379 mm FL (only 1 fish was longer than 333 mm FL) and samples had a standard deviation of 38 mm FL Slightly less than half (49%) of the population in 2006 was ≤240 mm FL (Table 9).

By regulation, harvest of cutthroat trout in Auke Lake is restricted to fish ≥356 mm FL (14 inches TL) and only a few (about 6) cutthroat trout in Auke Lake were estimated to be available for legal harvest in 2006.

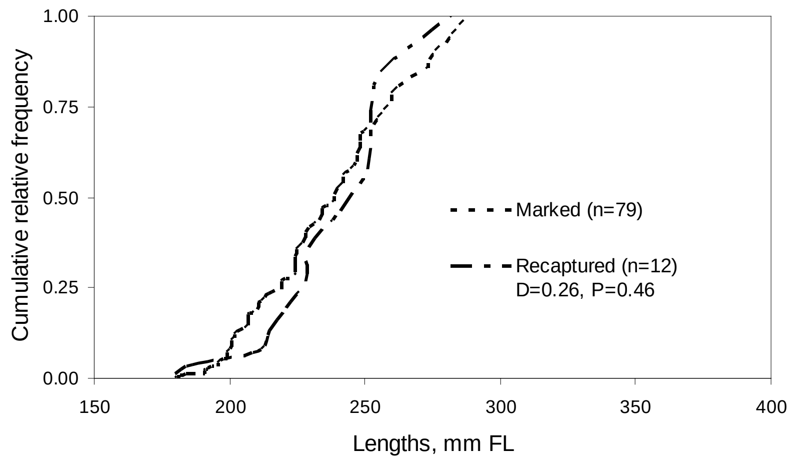

Figure 3.–Cumulative relative frequency of cutthroat trout ≥180 mm FL marked in the first event versus those recaptured in the second event in 2006.

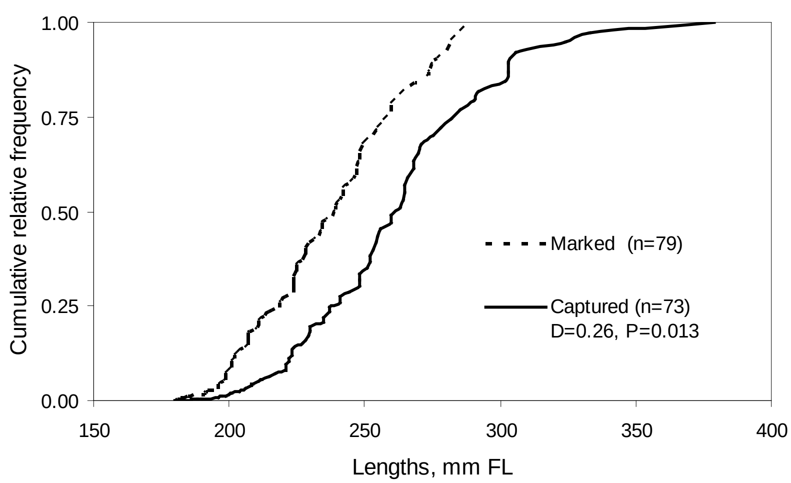

Figure 4.–Cumulative relative frequency of cutthroat trout ≥180 mm FL marked in the first event versus those captured in the second event in 2006.

Table 9.–Length composition and estimated abundance at length for cutthroat trout ≥180 mm FL in Auke Lake in 2005 and in 2006. Number sampled (nk), proportion (pk), abundance (Nk), and standard errors (SE) are shown for each 20-mm length class. Fish captured more than once were not used to calculate proportions.

Compositions in 2005					
Length k, mm FL	n_k	$\hat{p}_k$	**SE(** $\hat{p}_k$ **)**	$\hat{N}_k$	**SE(** $\hat{N}_k$ **)**
180–200	23	0.169	0.032	43	14
201–220	17	0.125	0.028	32	11
221–240	24	0.176	0.033	45	14
241–260	26	0.191	0.034	49	15
261–280	15	0.110	0.027	28	10
281–300	15	0.110	0.027	28	10
301–320	11	0.081	0.023	21	8
321–340	5	0.037	0.016	9	5
341–360	0	0.000	0.000	0	0
Total	136		$\hat{N}$ =	255	
Compositions in 2006					
Length k, mm FL	n_k	$\hat{p}_k$	**SE(** $\hat{p}_k$ **)**	$\hat{N}_k$	**SE(** $\hat{N}_k$ **)**
180–200	9	0.123	0.039	56	23
201–220	10	0.137	0.041	62	24
221–240	17	0.233	0.050	106	36
241–260	15	0.205	0.048	93	32
261–280	11	0.151	0.042	68	26
281–300	4	0.055	0.027	25	13
301–320	4	0.055	0.027	25	13
321–340	2	0.027	0.019	12	9
341–360	0	0.000	0.000	0	0
361–380	1	0.014	0.014	6	6
Total	73		$\hat{N}$ =	454	

SURVIVAL

A total of 18 PIT-tagged cutthroat trout immigrated into Auke Lake in fall 2005 (Hoover 2007). Twelve of those fish emigrated from the lake in spring 2006 (Hoover 2008), leaving 6 that either remained in Auke Lake or died over the winter. None of the remaining 6 fish were caught while sampling in Auke Lake in 2006. However, even with this limited data a "worst-case" estimate of overwinter (2004–2005) survival of 67% (=12/18) can be generated for these PIT-tagged fish. Average overwinter survival for PIT-tagged sea-run migrants in Auke Lake (1998–2005) has been 62% (Table 10). These overwinter survival estimates are much higher than our annual survival rate estimates because the later include all other sources of spring and summer mortality, such as that due to spawning (Table 10).

Table 10.–Estimated survival rates for cutthroat trout in Auke Lake, 1997–2006.

Year	Overwinter survival[a]	Annual survival[b]
1997–1998	67%	-
1998–1999	58%	41%
1999–2000	60%	35%
2000–2001	74%	37%
2001–2002	48%	22%
2002–2003	65%	44%
2003–2004	52%	45%
2004–2005	68%	27%
2005–2006	67%	-
average	62%	36%

[a] Estimates for PIT tagged fall immigrants (Lum et al. 1999, 2000; 2001; 2002; Lum and Taylor (2004, 2006, 2006a, and 2006b).

[b] Estimates from the JS model (Table 8).

The data from this study has been electronically archived by ADF&G, Research and Technical Services in Anchorage, Alaska (Appendix A8).

DISCUSSION

Since 1997, the cutthroat trout assessments in Auke Lake, along with those at the Auke Creek weir, have provided a rare time series of abundance, survival, growth, migration timing, and other life history information for both resident and anadromous species in a cutthroat trout system. Analysis of the monitoring data (e.g. Lum and Taylor 2006 b-c) has contributed much to our understanding of this, and other similar cutthroat trout systems.

An estimated harvest of 40 cutthroat trout occurred in Auke Lake during 2005 and 0 fish were estimated harvested during 2006 (Tables 1 and 2). However, the harvest estimates for Auke Lake are very imprecise due to the low sampling rate: 2 anglers in 2005 and 8 in 2006.

The Auke Lake watershed contains the only sea-run cutthroat trout population in Southeast Alaska that has consistent emigration counts for greater than 10 years. This emigrant data has also been used by fisheries managers as a surrogate for run timing and length composition in other sea-run cutthroat systems, as well as magnitude and scope of emigrants to watershed size. The importance of this long-term cutthroat trout emigration data is also important to enable an understanding of potential impacts caused by climate change (Taylor 2008).

Observations of the relationship between the annual estimated abundance of cutthroat trout in Auke Lake and the corresponding emigrant weir count (Figure 5) suggests that abundance is loosely related to the corresponding emigrant count (in the same year). A complete analysis of this relationship is difficult because the start date for the abundance estimate occurred prior to the emigration midpoint in 2000 and 2001 and after the midpoint in all other years; all emigration occurred prior to sampling in 2004 and 2005. However, this relationship could alert managers to stock status issues in the lake, provided that the emigration counts generated at the weir continue.

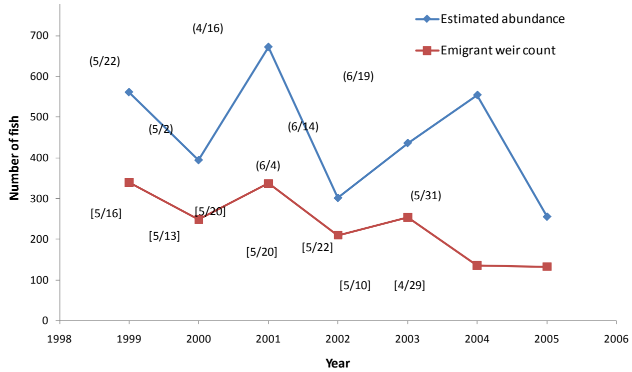

Figure 5.–Annual abundance estimates of cutthroat trout in Auke Lake and emigrate counts through Auke Creek weir for 1999 2005. Start date of annual abundance sampling is show in () while date of emigration midpoint is shown in [].

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). This heterogeneity may arise because of the different life history trajectories of resident and anadromous fish using the lake, and perhaps age dependent mortality (Lum and Taylor 2006a). The heterogeneity imparts some bias to the estimates. Assuming, for illustration, that estimates from generalized (in POPAN) JS models for 2000–2003 are unbiased, our JS estimates for this period (Table 8) would be biased low by about 9%. Survival estimates should suffer less from the heterogeneity (Pollock et al. 1990); they would be biased low by 5% using the comparison above. Although there is no confidence in applying the generalized JS model to these data, one apparent conclusion from the generalized model is that fish first captured *prior* to the most recent sampling event "survive" at a lower (almost one-half) rate than newly captured fish. The relatively poor "survival" of the older capture group may result from permanent emigration of smolt, and age dependant mortality.

RECOMMENDATIONS

Cutthroat trout that overwinter in Auke Lake are known to enter other Juneau roadside streams to spawn shortly after emigration (Jones and Seifert 1997). Efforts to "enhance" the cutthroat trout population in Auke Lake between 1981 and 1993 may have negatively impacted local streams as eggs collected from ripe females emigrating from Auke Lake might otherwise have been deposited in them. The fecundity of cutthroat trout is low and on average, an 11-inch female cutthroat has only 263 eggs (Harding and Jones 2005) and a large proportion of ripe emigrants would be required to maintain any hatchery program.

The telemetry study of Auke Creek emigrants (Jones and Seifert 1979) tracked fish into several Juneau roadside streams as small as 7 – 8 cm wide. Fish traps designed to capture both immigrant and emigrant fish were installed on 2 of the smaller steams in 1995 to capture mature sea-run cutthroat trout to radiotag. Two mature immigrants were captured in Bridget Cove Creek and only 1 in Shrine Creek, suggesting that in some of smaller Juneau roadside streams the entire spawning population may consist of only a handful of fish (unpublished data, ADF&G, Division of Sport Fish, Douglas). Thus, any future efforts to utilize mature Auke Lake emigrants could have undesirable consequences on theses small populations and the potential impacts to other Juneau roadside streams will need to be considered.

The combination of the Auke Lake studies and the Auke Creek weir facility has created a unique opportunity to contribute to the rangewide understanding of life history strategies of sea-run cutthroat trout. The authors recognize the limitations of this report but recommend that a future report encompasses an analysis of individual PIT tag data from the weir and abundance studies to possibly identify previously unknown migrations patterns or life history forms.

ACKNOWLEDGMENTS

We would like to thank Kurt Kondzela, Ken Koolmo, Karen Koolmo, and John DerHovanisian who helped with the lake sampling and logistics. This report is based on previous reports on the cutthroat trout in Auke Lake by Judith Lum and Sidney Taylor.

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APPENDIX A

Appendix A1.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

- Marked fish mix completely with unmarked fish between events;
- Every fish has an equal probability of being captured and marked during the first event;

or,

- Every fish has an equal probability of being captured and examined during the second event.

To evaluate these three assumptions, the chi-square statistic can be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-"Complete mixing test"[a]

	Time/Area Where Recaptured				Not Recaptured
Area/Time Where Marked	1	2	…	t	(n_1-m_2)
1					
2					
…					
S					

II.-"Equal Proportions test"[b]

	Area/Time Where Examined			
	1	2	…	T
Marked (m_2)				
Unmarked (n_2-m_2)				

III.-Pooled version of "Complete mixing test"[c]

	Area/Time Where Marked			
	1	2	…	S
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

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[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, t) are the same among sections: H_0: $\theta_{ij} = \theta_j$ (test for homogeneity of the rows of the s by (t+1) table.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i\theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum I. Accepting H_0: is consistent with an equal probability of capture during the first event.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j\theta_{ij}p_j$ = d, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

Appendix A2.–Detection of size- and/or sex-selective sampling during a two-sample mark–recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o
There is no size/sex selectivity detected during either sampling event.		
Case II:		
Reject H_o	Fail to reject H_o	Reject H_o
There is no size/sex selectivity detected during the first event but there is during the second event sampling.		
Case III:		
Fail to reject H_o	Reject H_o	Reject H_o
There is no size/sex selectivity detected during the second event but there is during the first event sampling.		
Case IV:		
Reject H_o	Reject H_o	Either result possible
There is size/sex selectivity detected during both the first and second sampling events.		
Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

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B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then overall composition parameters (p_k) are estimated by combining within stratum composition estimates using:

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

and,

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

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size *k* among fish in stratum *i*;

$\hat{N}_i$ = the estimated abundance in stratum *i*; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A3.–Capture histories for the Auke Lake Jolly-Seber model, 1998–2006.

Capture history[a]	Frequency	Capture history[a]	Frequency	Capture history[a]	Frequency
000000001	122	000010100	2	001111000	1
000000010	73	000011000	64	010000000	236
000000011	9	000011010	3	010010000	2
000000100	168	000011011	1	010100000	4
000000101	2	000011100	14	011000000	78
000000110	28	000011110	1	011001000	1
000000111	1	000011111	1	011010000	5
000001000	193	000100000	151	011011100	1
000001001	1	000100110	1	011100000	1
000001010	6	000101000	2	011110000	2
000001100	61	000110000	28	100000000	63
000001101	2	000111000	10	101000000	4
000001110	7	001000000	157	110000000	20
000001111	1	001010000	7	111000000	2
000010000	113	001100000	31		
000010010	2	001110000	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 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 marked cutthroat trout seen in 2005 and recaptured in 2006 by stratum, and chi-square test for mixing between years.

		Numbers unique marks seen in 2006 by stratum					
Stratum fish was marked	Total marks seen in 2005	A[a]	B[b]	C[c]	Total (all strata)	Number not seen	Proportion recaptured
A	49	2	1	1	4	45	0.08
B	41	2	2	1	5	36	0.12
C	52	1	2	1	4	48	0.08
Total	123	5	5	3	13	129	0.09
Unmarked fish caught		40	40	43	123		
Total caught in recapture event		45	45	46	136		
Marked fraction		0.11	0.11	0.065	0.096		

"Equal Proportion" test: $X^2 = 0.74$, 2 df, P = 0.69, *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	88.00
Captured in 2002 and not recaptured in 2003		46.00	113.00
χ^2 = 10.126, 1 df, P = 0.002	$\hat{p} \rightarrow$	0.207	0.438

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

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Component 1 test for 2003		First captured in 2002	First captured in 2003
Captured in 2003 and recaptured in 2004		21.00	78.00
Captured in 2003 and not recaptured in 2004		78.00	193.00
χ^2 = 2.120, 1 df, P = 0.145	$\hat{p} \rightarrow$	0.212	0.288

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 2004, not in 2003		1.00	0.00	4.00
χ^2 = 4.183, 2 df, P = 0.124	$\hat{p} \rightarrow$	0.75	1.00	0.955

Component 1 test for 2004		First captured in 2003	First captured in 2004
Captured in 2004 and recaptured in 2005		13.00	31.00
Captured in 2004 and not recaptured in 2005		78.00	168.00
χ^2 = 0.081, 1 df, P = 0.776	$\hat{p} \rightarrow$	0.143	0.156

Component 2 test for 2004		Captured in 2002, not in 2003	Captured in 2002 and 2003	First captured in 2003
Captured in 2004		3.00	17.00	71.00
Captured in 2005, not in 2004		2.00	4.00	7.00
χ^2 = 5.167, 2 df, P = 0.076	$\hat{p} \rightarrow$	0.60	0.810	0.910

Component 1 test for 2005		First captured in 2004	First captured in 2005
Captured in 2005 and recaptured in 2006		4.00	9.00
Captured in 2005 and not recaptured in 2006		48.00	73.00
χ^2 = 0.392, 1 df, P = 0.532	$\hat{p} \rightarrow$	0077	0.110

Component 2 test for 2005		Captured in 2003, not in 2004	Captured in 2003 and 2004	First captured in 2004
Captured in 2005		12.00	11.00	29.00
Captured in 2005, not in 2006		1.00	2.00	2.00
χ^2 = 0.938, 2 df, P = 0.626	$\hat{p} \rightarrow$	0.923	0.846	0.935

Appendix A6.–Summary of capture probabilities by tag group and sampling year for the Jolly-Seber experiment at Auke Lake. See Appendix A3 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	0.438	0.938	1.000	0.927
2003	0.212	0.288	0.750	1.000	0.955
2004	0.143	0.156	0.600	0.810	0.910
2005	0.077	0.110	0.923	0.846	0.935
Mean	0.137	0.242	0.813	0.826	0.915

Appendix A7.–Number of marked cutthroat trout seen in 2006 trip 1 and recaptured in 2006 trip 2 by stratum, and chi-square test for mixing within 2006.

		Numbers unique marks seen in 2006 trip 2 by stratum					
Stratum fish was marked	Total marks seen in 2006 trip1	A[a]	B[b]	C[c]	Total (all strata)	Number not seen	Proportion recaptured
A	30	5	1	0	6	24	0.20
B	28	1	2	1	4	24	0.14
C	21	0	0	2	2	19	0.10
Total	61	6	3	3	12	67	0.15
Unmarked fish caught		19	17	25	61		
Total caught in recapture event		25	20	28	73		
Marked fraction		0.24	015	011	0.16		

"Equal Proportion" test: X^2 = 1.74, 2 df, P = 0.42, *Accept H_o: marked fraction is constant across recovery strata*

"Complete mixing" test: X^2 = 1.08, 2 df, P = 0.58, *Accept H_o: recovery fraction is constant across marking strata*

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

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

[c] Study areas 7 and 8.

Appendix A8.–List of computer data files archived from this study.

Data File	**Description**
Auke_Pop_anaylsis_06.xls	Excel file of cutthroat trout PIT tagging information for the abundance study in Auke Lake, 2006.
Cutts KS Work Bob.xls	Excel file summarizing the tagging data (PIT tags and fish length by capture area), movement matrices, length composition and abundance by length class.
2006 Auke GOF Tests.xls	Excel file showing the GOF test for the JS model.