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Abundance, Length Composition, and Annual Mortality of Cutthroat Trout at Neck Lake, Southeast Alaska, 1996 through 1998

by

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Alaska Department of Fish and Game **Division of Sport Fish**

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
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

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ABSTRACT

The population status of cutthroat trout *Oncorhynchus clarki* at Neck Lake in Southeast Alaska was examined from 1996 through 1998 in response to angler concerns about restrictive harvest regulations and the potential effects of introduced coho salmon *Oncorhynchus kisutch* on the trout population. Sampling in 1996, 1997, and 1998 (twice) permitted use of a Jolly-Seber (JS) model to estimate abundance in 1997 and 1998. Also, a two-event (Petersen/Darroch) closed population (CP) model was used to estimate abundance in 1998. An estimated 2,982 (SE = 232) cutthroat trout were present in 1997; 2,742 (SE = 243) were present in mid-May 1998 under the JS model, and 3,151 (SE = 144) were present in May 1998 under the CP model.

Key words: Southeast Alaska, Neck Lake, cutthroat trout, abundance, natural mortality, mark-recapture, length composition, coho salmon stocking

INTRODUCTION

Neck Lake is one of three cutthroat trout *Oncorhynchus clarki* lake fisheries with boat ramp access on the Prince of Wales Island (POW) road system. With 3,626 km of permanent road, the POW road system is the most extensive road system in Southeast Alaska. Although fishing effort and cutthroat harvests at the lake are not well-documented, this lake is believed to be an important destination for local anglers.

In 1994 the Alaska Board of Fisheries passed regionwide regulations that implemented a daily bag limit of two cutthroat trout with a minimum size limit of 12 inches in total length, and bait was prohibited in freshwater 10 months of the year. Residents from the communities on POW voiced concerns that the minimum size limit of 12 inches was too restrictive for Neck Lake because very few cutthroat trout reached this size.

Plans to rear hatchery-produced coho salmon *O. kisutch* fry in Neck Lake also raised concerns about the ability of the lake to sustain cutthroat trout harvests. Starting in 1996, the Southern Southeast Regional Aquaculture Association (SSRAA) began rearing coho salmon in net pens in Neck Lake. The fry were reared from July to November, and then released into the lake to forage and overwinter. The following spring, most surviving juvenile coho salmon emigrated from the lake as smolts. It is thought that juvenile coho salmon might compete with cutthroat trout for both habitat and food as they overwintered in the lake or inlet streams (Glova 1984). Coho salmon that do not smolt after their first winter in the lake might also compete with cutthroat trout year-around (Glova 1986). In contrast, larger cutthroat trout (>250 mm) might benefit from the rearing coho salmon, as they utilize them for food (Beauchamp et al. 1992).

In response to both of these issues, the Alaska Department of Fish and Game (ADF&G) initiated a project in 1996 to assess the cutthroat trout population at Neck Lake. Results of the project include estimates of abundance in 1997 and 1998 and length distributions of cutthroat trout ≥180 mm fork length (FL) from 1996 through 1998. Although introduced coho salmon might have significantly impacted the cutthroat trout population prior to 1997, we felt this study would provide valuable data to help evaluate the impacts of the coho rearing program on the resident cutthroat trout in Neck Lake.

STUDY AREA

Neck Lake is located 3 km southeast of the small community of Whale Pass, Alaska on Prince of Wales Island (Figure 1). The lake is approximately 6.4 km long and 0.7 km in average width, with a surface area of 373 ha. Situated at an elevation of 27 m, the lake has a mean depth of about 15 m and a maximum depth of 58 m. A barrier falls below the outlet of Neck Lake precludes the upstream migration of anadromous fish. Resident fish species include cutthroat

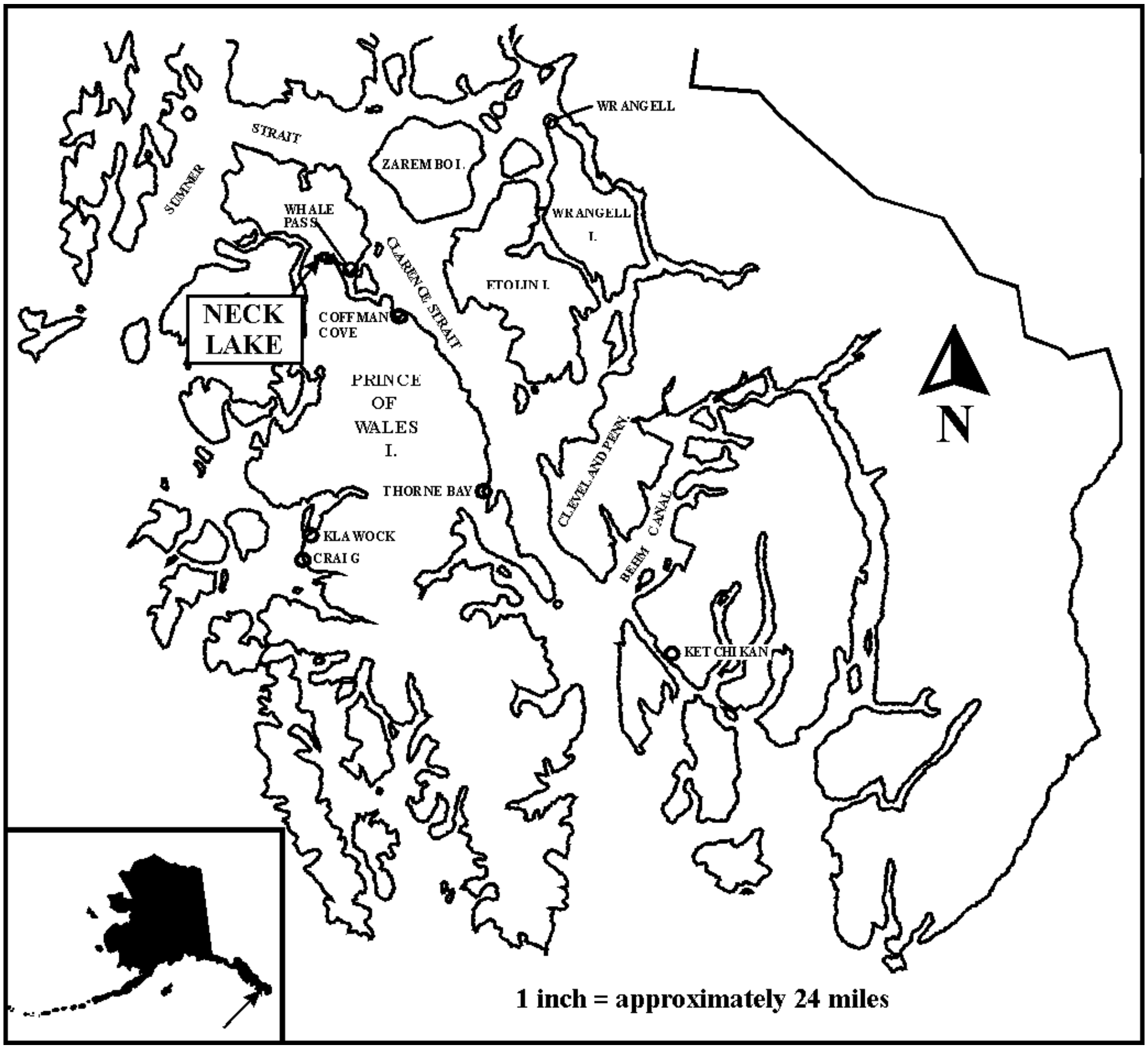

Figure 1.–Location of Neck Lake on Prince of Wales Island in southern Southeast Alaska.

trout, kokanee *O. nerka*, Dolly Varden *Salvelinus malma* and threespine stickleback *Gasterosteus aculeatus* and sculpins *Cottidae* sp.

In 1990 the United States Forest Service (USFS) and ADF&G cooperated in building a boat ramp at Neck Lake. It was upgraded in 1996.

In 1996, approximately 609,000 coho salmon were reared in net pens in Neck Lake from July through November and then released in the lake to forage and overwinter. During 1997 and 1998, 1.2 million coho salmon were similarly reared and released, and SSRAA plans to rear and release up to 1.4 million coho salmon annually.

Sport harvest and catch of cutthroat trout in Alaska is estimated annually using a mail survey that randomly samples anglers who have purchased Alaska sport fishing licenses (e.g., Howe et al. 1997). Since Neck Lake is a relatively small fishery and not specifically delineated on the postal survey, effort and harvest are estimated with very poor precision. Estimated fishing effort at Neck Lake during 1996, 1997, and 1998 ranged between 47 and 72 angler-days per year while annual harvests were ≤81 cutthroat trout (Statewide Harvest Survey database, ADF&G, Sport Fish Division, Anchorage). However, because these estimates were based on few (1 to 3) angler responses each year, they are considered unreliable.

METHODS

Two mark-recapture experiments were conducted to estimate the abundance, survival, and length composition of cutthroat trout ≥180 mm FL in Neck Lake. Ten-day sampling events were conducted in May 1996, May 1997, and in both May and June 1998. A Jolly-Seber (JS) model for an open population was used to estimate abundance (N) in 1997 and 1998 and the annual survival rate (ϕ) of cutthroat trout. Also, a two-event closed population (CP) model was used to estimate abundance in 1998. Fish captured more than once during a single sampling trip were treated as being caught only once.

The first three sampling trips occurred from May 15 to May 24, 1996, from May 20 to May 30, 1997, and from May 13 to May 22, 1998. The final sampling trip began eight days after the third sampling trip, spanning the period between May 29 and June 7, 1998.

The lake was divided into three areas of roughly equal size to help evaluate the experimental assumptions for the CP experiment (Figure 2). The three sampling areas (A, B, and C) were each further subdivided into three subareas (numbered 1 through 9, see Figure 2), so that daily sampling could proceed systematically from one end of the lake to the other. During each 10-day sampling event in 1996 and 1997, 28 baited hoop traps (BHT) were systematically moved through the nine subareas so that the total amount of gear set was uniformly distributed across all areas of the lake ≤40 m in depth. Sampling in each trip in 1998 proceeded just as before except that only 15 traps were set each day. Trap placement was determined by arbitrarily selecting a predetermined number of points on enlarged maps of each sampling area. Traps were set overnight, and the depth at which each BHT was set was measured by fathometer. In addition, hook-and-line (H&L) sampling was conducted by casting and trolling small lures from a boat as it traversed the lake's perimeter.

BHT used to capture cutthroat trout were 1.4 m long and consisted of four 0.6-m-diameter hoops with 9-cm-diameter throats attached to the first and third hoops. Traps were constructed of knotless nylon netting with a mesh size of 1 cm. Salmon eggs disinfected in 1% betadine solution for 15 minutes and cured with Borax were suspended in a perforated bait container within each trap. Hook-and-line sampling was conducted by casting small spoons, spinners, and other lures so that all shoreline areas at depths shallower than about 6 m were fished with similar effort.

All cutthroat trout ≥180 mm FL sampled were examined for marks, measured to the nearest mm FL, tagged with a numbered anchor T-bar tag (if unmarked), given a secondary mark to permit estimation of tag loss, and released in the area where captured.

Tags were inserted on the left side of the fish immediately below the dorsal fin. Secondary marks included clipped adipose fins in 1996 and partial removal of ventral fins in 1997. In 1998, shallow clips of the upper (trip 1) and lower (trip 2) caudal fins were used as controls against tag loss. The two marks applied in 1998 prevented tag loss in 1998 from compromising the CP abundance estimate. A scale sample was collected from the caudal peduncle directly above the lateral line of each newly captured fish; redundant fish captured more than once during a sampling trip were not scale sampled. Cutthroat trout <180 mm FL, Dolly Varden, and kokanee captured were only counted and released.

ESTIMATION OF ABUNDANCE IN 1997 UNDER THE JS MODEL

The JS model requires the following assumptions (Seber 1982:196,223; Pollock et al. 1990:18,24) to estimate abundance in late-May 1997 and in mid-May 1998:

1. every fish in the population at the time of the *i*th sample has the same probability of capture;
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;

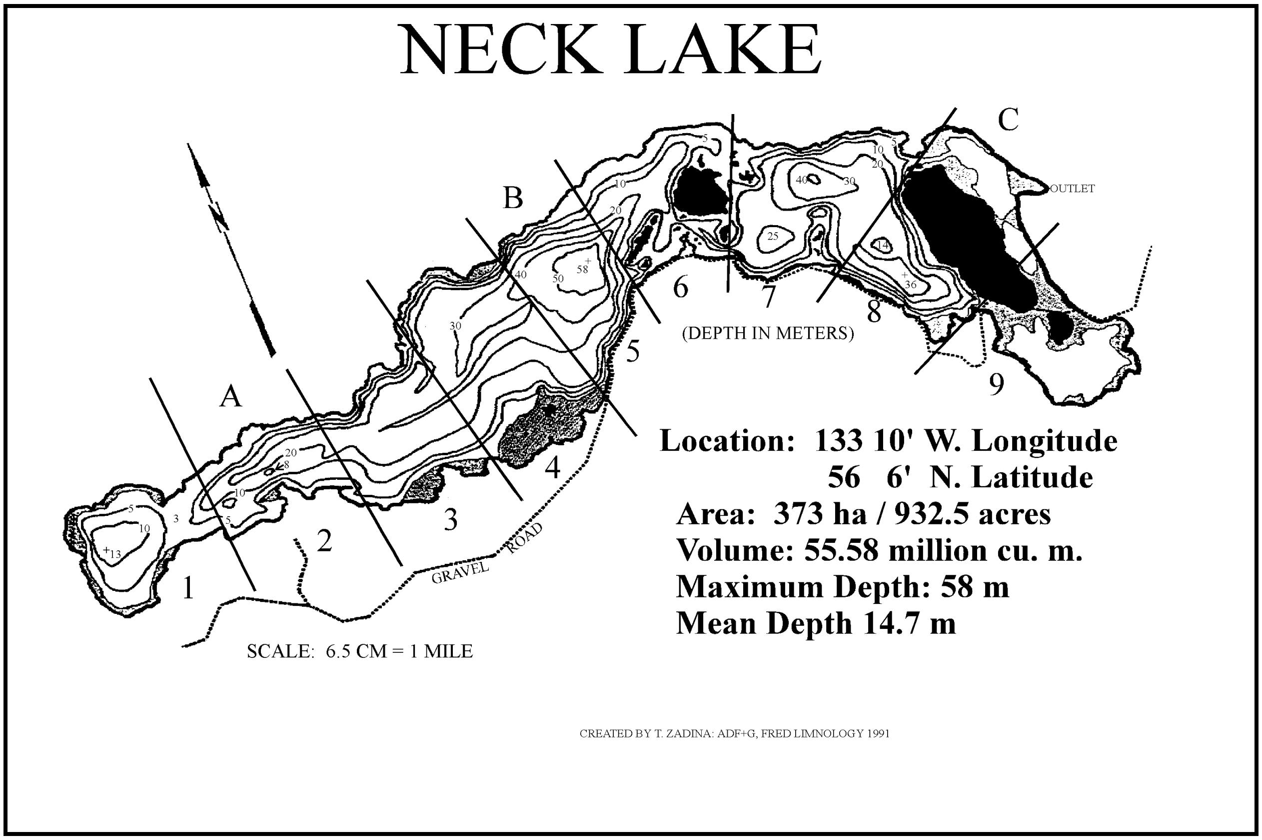

Figure 2.–Bathymetric map of Neck Lake showing study site with sampling area and subarea divisions (T. Zadina, ADF&G). Area A is divided into subareas 1–3, area B into subareas 4–6, and area C into subareas 7–9.

4. marks are not lost or overlooked;
5. all samples are instantaneous (i.e., sampling time is negligible).

The JS and Lincoln-Petersen abundance estimators both assume that the proportion of marked fish in the sample is representative of that in the population. Formulae for estimates of abundance and survival and an intuitive basis for the JS model can be found in Seber (1982:200) and Pollock et al. (1990:20). The main objective of this research suggests use of the "full" Jolly-Seber model, which provides k-2 survival rate estimates and k-2 abundance estimates (k = number of sampling events).

Two contingency table goodness-of-fit (GOF) tests (Pollock et al. 1985) were used to test the assumptions of homogeneous capture and survival probabilities. The tests compare two groups of fish marked in the experiment: newly marked and previously marked. Both tests have similar abilities to detect heterogeneous capture probabilities (Pollock et al. 1990:24). The first portion of the two-component test is equivalent to the Robson (1969) test for short-term mortality. Note that "short-term" refers to less than a *one-year* period in this experiment. Pollock et al. (1990:24) report the second test component to be the better of the two at detecting heterogeneous survival probabilities. The sum of chi-squares from each component forms an omnibus test for violations of the first three assumptions listed above. However, certain violations of these assumptions (permanent trap response and permanent lowering of survival rate due to handling and marking) cannot be detected by the tests (Pollock et al. 1985, 1990:24).

The GOF tests indicated the full JS model did not fit the data ($\alpha = 0.1$); thus a more generalized JS model which compensates for the heterogeneity among marked groups was fit to the data. GOF statistics from the competing models and a likelihood-ratio test (Brownie and Robson 1983) were used to select among the 2 models.

The condition that probability of capture is the same for all fish within a sampling event can be waived in an experiment based on the JS model if marked and unmarked fish mix completely between sampling events (Seber 1982). A test for mixing *by mark status* compared the recapture/ capture (R/C) fractions of fish caught with traps on the lake bottom to those caught near shore with hook-and-line, *using only fish marked with traps in the previous sampling event.* If $(R/C)_{trap} > (R/C)_{H\&L}$, lack of complete mixing was indicated; if $(R/C)_{trap} = (R/C)_{H\&L}$, complete mixing was indicated; and if $(R/C)_{trap} < (R/C)_{H\&L}$, trap shyness was indicated. A chi-square (2×2 contingency table) statistic ($\alpha = 0.1$) was used for the test.

The assumption of equal probabilities of capture can also be violated by differential vulnerability to sampling gear (size-selective sampling). Because it was reasonable to assume growth and recruitment between sampling events in 1998 was negligible, a direct test for size-selective sampling in 1998 was made, as explained below in the section on the CP model. Another test for size-selective sampling was conducted by comparing an abundance estimate for the entire population of cutthroat trout ≥180 mm FL against the sum of estimates obtained by stratifying the JS experiment into two size classes. If size-selective sampling was not significant, the sum of the stratified estimates should not be significantly different from the estimate for all fish ≥180 mm FL. We stratified the capture data at 220 mm FL, which is near the mid-point in the data, as this has proven effective in other studies. Adequacy of the stratified data set for large fish was tested using the GOF test noted above. However, the procedure cannot be applied to the smaller size class, because marks applied at time i-1 will more likely have grown out of the analysis than fish marked at time i.

The assumption that all fish have the same chance of surviving from the ith to the (i+1)th sampling implies the absence of significant age-dependent mortality rates for cutthroat trout ≥180 mm FL (Manly 1970). Little evidence of age-dependent mortality was found for cutthroat trout ≥180 mm FL in Florence Lake (Rosenkranz et al. 1999). An indication of size (or age) dependent mortality in this experiment can be obtained by comparing survival estimates from the larger size class of the length-stratified analysis (described above) to the survival estimates from the unstratified analysis. If the two estimates were similar, the absence of a strong age-dependent mortality schedule at Neck Lake would be indicated. Note that annual survival rate estimates for the small size class are meaningless, because small fish can grow into the larger size class between events.

Assumption 3 was evaluated by direct examination of the capture histories (mortality status by year) from each event. Double-marking fish with secondary marks addressed assumption 4. Tag loss was calculated for each sampling date/year. Estimates of loss >10% would necessitate special consideration of bias in the estimates.

Assumption 5 seemed reasonable in this experiment, for sampling in each event was confined to 10 days. Because 10 days is a relatively short period of time in the context of the experiment, we assumed that additions and losses (recruitment and death) to the population during each sampling event were insignificant.

Capture histories for the JS analysis were summarized using the computer programs Excel and SAS (SAS 1990) and then input to two computer programs (JOLLY and POPAN) to obtain the desired sampling statistics, GOF tests, and parameter estimates. Program JOLLY was developed by Brownie et al. (1986) at the Patuxent Wildlife Research Center (see Pollock et al. 1990 for a description of JOLLY), and POPAN was developed by Arnason and Schwarz (1995) at the University of Manitoba.

Estimation of Abundance in 1998 under the CP Model

Lincoln-Petersen and Darroch CP models (Seber 1982:59,431) were considered for estimating abundance in May 1998, based on whether stratification by area of the lake was required to meet modeling assumptions. Assumptions of the two-event CP experiment were:

1. the population was closed; i.e., recruitment (or immigration) and death (or emigration) did not both occur between sampling events;
2. every fish had an equal probability of being marked during the first event, *or* every fish had an equal probability of being sampled during the second event, *or* marked and unmarked fish mixed completely between events;
3. marking did not affect the catchability of a fish; and
4. fish did not lose marks between events, *and* marks were recognized in the recovery sample and reported.

The closure assumption was not tested but seemed reasonable given the relatively short time (8 days) between the two sampling events, and that significant natural mortality and growth recruitment was not expected at this time of the year. In a similar lake on Admiralty Island, spawning migrations to very small inlet streams began in late April and were concluded by early June (Harding 1995:27). Thus, it is possible that some spawning fish had not reentered the lake prior to the start of the first sampling trip on May 13. Since post-spawning fish are large relative to all fish sampled, such an immigration might be indicated if lengths of fish sampled increased substantially between trips. Similarly, significant growth recruitment between sampling events might be indicated if fish lengths declined significantly between trips. A two-sample Kolmogorov-Smirnov (KS) test (Conover 1980) was used to detect significant differences in the lengths of fish caught between sampling trips.

Size-selective sampling (a violation of the second assumption) was investigated with two KS tests (Appendix A1). If size-selective sampling occurred during the second sampling event ($P < 0.05$), the experiment would be stratified by fish size.

Two chi-square tests (Seber 1982:438-39, Arnason et al. 1996) were used to determine if the data were consistent in a spatial sense with the second assumption. Data were compiled by marking and recovery area (ends and middle of the lake) and input to SPAS (Arnason et al. 1996) to complete these consistency tests, any beneficial data pooling, and to estimate abundance. The chi-square tests estimate probabilities that 1) fish marked in the different initial strata were recaptured at equal rates in the second sample, and 2) marked fractions were similar in each recovery stratum. If either of these tests yielded a non-significant result, strata would be pooled to simplify the model. If all spatial strata were pooled, a Petersen model remained to estimate abundance.

Assumption 4 should be robust in this experiment, because all fish were double-marked and technicians were instructed to rigorously examine all captured fish for marks. Evidence of tag loss or tagging stress was recorded for every fish handled. Because all tagged fish were given a permanent secondary mark (a finclip), tag loss could be estimated.

We cannot test for effects of marking on catchability (assumption 3) with only two sampling events. However, a recent experiment (Harding et al. 1999) provides some evidence that capture with BHT and tagging does not lead to a significant (35%) short-term trap avoidance reaction.

LENGTH COMPOSITION

Size-selectivity in sampling was investigated according to the protocols in Appendix A1. When adjustment for size selective sampling was not needed, the proportion of fish in the population within length category *a* was estimated:

$$\hat{p}_a = \frac{n_a}{n} \tag{1}$$

$$\text{var}(\hat{p}_a) = \frac{\hat{p}_a(1-\hat{p}_a)}{n-1} \tag{2}$$

where n the number of fish measured for length and n_a is the number from this sample in length increment a.

The abundance in the population within length increment a was estimated (Goodman 1960):

$$N_a = \hat{p}_a \hat{N} \tag{3}$$

$$\mathrm{var}[\hat{N}_a] = \mathrm{var}(\hat{p}_a)\,\hat{N}^2 + \mathrm{var}(\hat{N})\,\hat{p}_a^2 - \mathrm{var}(\hat{p}_a)\,\mathrm{var}(\hat{N}) \qquad (4)$$

where $\hat{N}$ is estimated abundance from the mark-recapture experiment.

CATCH PER UNIT EFFORT

Mean catch per unit effort (CPUE) by sampling period and gear type was calculated by standard statistical methods. These data are useful for planning and for comparing relative catch rates at different lakes and/or times of the year.

RESULTS

ABUNDANCE IN 1997 UNDER THE JS MODEL

In 1996, 1,625 unique cutthroat trout between 180 and 424 mm FL were sampled and returned to Neck Lake (Appendices A2 and A3). During 1997, 1,448 fish between 180 and 368 mm FL were sampled and returned to the population. Capture rates during the two sampling trips in 1998 were similar; together, 1,517 unique cutthroat trout were captured. Excluding fish with lost anchor T-bar tags, 291 of the fish sampled in 1997 and 404 of those sampled in 1998 had been marked in prior years.

Tag loss was estimated at 6% from 1996 to 1997 and at 4% overall for fish recovered in 1998, and thus discounted as a significant factor in the analysis. Also, contingency table tests for mixing by mark status indicate complete mixing of marked fish between capture gears from 1996 to 1997 (χ^2 = 1.51, P = 0.22), and between 1997 and 1998 (χ^2 = 0.06, P = 0.80).

The first GOF test for homogeneous capture/survival probabilities (Robson's test for short-term mortality, component 1 in Table 1, panel A, and Table 2) shows the full JS model does not fit the data well. The second GOF test (Tables 1 and 3) was, however, not significant. The first test shows that fish newly tagged in 1997 were captured at a significantly lower rate in 1998 (22%, compare p values) than fish first marked in 1996 and captured in both 1997 and 1998 (P = 0.011; Table 2, panel A). A similar difference (18%) occurs for fish newly tagged in 1998 (P = 0.047, Table 2, panel B). The 18–22% lower recapture rates were largely restricted to smaller (<220 mm FL) fish, since capture rates for the large fish (Table 1, panel B) do not vary significantly.

The lack of fit suggested by Robson's test led to fitting a generalized form of the JS model, which includes a one-period effect on survival related to handling and tagging. This model (Brownie and Robson 1983) allows survival rates of newly captured fish to differ from survival rates of previously captured fish. GOF statistics and estimates of survival (but not abundance) for this generalized model are implemented (as model "2") in JOLLY. GOF statistics for model 2 were much improved (χ^2 = 1.24, P = 0.54) over the full model, and a likelihood ratio test comparing the two models strongly rejected (χ^2 = 10.4, P = 0.005) the less general (full) JS model. Thus, population parameters were estimated using the more general model (Table 4).

The estimated survival rate for all fish (0.51) and large fish (0.51) were identical; survival rates for

Table 1.–Summary of GOF tests for the JS model.

PANEL A: Trout ≥180 mm FL		Test statistic	Degrees of freedom	P-value
Component 1	1997	6.50	1	0.011
	1998[a]	3.95	1	0.047
Component 2	1998[a]	1.24	2	0.537
Overall		11.7	4	0.020
PANEL B: Trout ≥220 mm FL		**Test statistic**	**Degrees of freedom**	**P-value**
Component 1	1997	1.76	1	0.185
	1998[a]	0.501	1	0.479
Component 2	1998[a]	0.564	2	0.754
Overall		2.82	4	0.588

[a] First sampling trip in 1998, May 13–20.

Table 2.–Breakdown for 1997 and 1998 (trip 1) of statistics for component 1 of the GOF tests for the JS model (p = probability of capture for each group of tagged fish).

PANEL A: TEST FOR 1997		**First captured in 1996**	**First captured in 1997**
Captured in 1997 and recaptured later		80.00	238.00
Expected value		63.91	254.09
Captured in 1997 and not recaptured later		211.00	919.00
Expected value		227.09	902.91
χ^2 = 6.49, 1 df, P = 0.011	p →	0. 27	0.21
PANEL B: TEST FOR 1998 (TRIP 1)		**First captured before 1998 (trip1)**	**First captured in 1998 (trip 1)**
Captured in 1998 (trip1) and recaptured later		78.00	168.00
Expected value		66.22	179.78
Captured in 1998 (trip 1) and not recaptured later		164.00	489.00
Expected value		175.78	477.22
χ^2 = 3.95, 1 df, P = 0.047	p →	0.32	0.26

small fish (180–220 mm FL) were nearly identical (0.52) (Table 4). These estimates are those for previously marked fish, since they best estimate the rate for untagged fish during the experiment. Note that model 2 yields one less estimate of survival than does the full JS model. Because annual harvests at Neck Lake were low (≤ 81 fish) from 1996 through 1998, the estimated annual survival rates for all (>180 mm FL) and large (>220 mm FL) fish essentially estimate the natural survival rates for these size groups.

Abundance was estimated in POPAN (model "3") which computes a modified estimate of the number of marked fish in the population rather than estimating separate survival rates for the two groups of marked fish (Arnason and Schwarz 1995). Abundance of cutthroat trout ≥180 mm FL in Neck Lake during mid-May 1997 was 2,982 (SE = 232; Table 4) and during May 1998 was 2,742 (SE = 243). Sampling did not appear size-selective as estimates of abundance obtained by summing estimates for small (≤220 mm FL) and

Table 3.–Breakdown for 1998 (trip 1) of statistics for component 2 of the GOF tests for the JS model (p = probability of capture for each group of tagged fish).

		Captured in 1996, not in 1997	**Captured in 1996 and 1997**	**First captured in 1997**
Captured in 1998 (trip 1)		52.00	52.00	138.00
Expected value		51.51	47.92	142.56
Captured in trip 2 (1998), not in trip 1 (1998)		34.00	28.00	100.00
Expected value		34.49	32.08	95.44
χ^2 = 1.24, 2 df, P = 0.537	p →	0.40	0.35	0.42

Table 4.–Estimates of abundance (N), survival (ϕ), and capture probability (p) from modified JS models of all cutthroat trout ≥180 mm FL (panel A)**, and for only small- and large-sized fish** (panels B and C). Estimates of ϕ (from JOLLY) are for previously tagged fish only, and thus estimate the survival rate of untagged fish. Estimates of N are from POPAN.

Trout size class	Year	N	SE(N)	ϕ	SE(ϕ)	p	SE(p)
Panel A: ≥180 mm FL	1996			na[a]	na		
	1997	2,982	232	0.51	0.060	0.482	0.039
	1998[c]	2,742	243			0.325	0.030
Panel B: 180–220 mm FL	1996			na[a]	na		
	1997	1,758	164	0.52[b]	0.069	0.471	0.046
	1998[c]	1,786	178			0.363	0.038
Panel C: >220 mm FL	1996			na	na		
	1997	1,171	162	0.51	0.060	0.511	0.073
	1998[c]	942	173			0.250	0.048

[a] Estimate unavailable using the model with a one-period effect of tagging on survival.

[b] Estimates of ϕ for small fish include rates of immigration to the larger size class as well as death.

[c] First sampling trip in 1998, May 13–20.

large (>220 mm) fish [2,929 (SE = 231) in 1997 and 2,728 (SE = 248) in 1998] were clearly not different from unstratified estimates (Table 4). Summary statistics and capture histories used in the JS analysis are given in Appendices A2 and A3, respectively; archived files used in this analysis are listed in Appendix A4.

ABUNDANCE IN 1998 UNDER THE CP MODEL

During the marking event, 899 unique cutthroat trout between 180 and 403 mm FL were marked and released alive. During the recapture event 864 unique cutthroat trout between 180 and 395 mm FL were examined; 246 of the fish captured in the recapture event had been marked during the marking event. There was no tag loss detected during the 1998 experiment. CPUE for cutthroat trout in traps declined slowly with increasing depth to near 0 fish/trap at 35 m. Sampling thus appeared to encompass the entire catchable population available to our gear.

The length distributions of cutthroat trout initially captured during the marking event and subsequently recaptured during the recapture events (Figure 3, top panel) were not significantly different (KS test, D_{max} = 0.0471, P = 0.76). Thus, stratification based on fish size was not indicated.

Mixing of marked fish between sampling areas occurred between sampling events (Table 5). We accepted the hypotheses that fish marked in different areas were recaptured at equal rates (P = 0.20, Table 6), and that marked fractions were similar in each recovery stratum (P = 0.24). Thus, spatial data were pooled and the Petersen model was used to estimate abundance.

Abundance of cutthroat trout ≥180 mm FL in Neck Lake in late May and early June 1998 was estimated at 3,151 (SE = 144). The 95% confidence interval (CI) for the estimate was 2,868 - 3,433 using the normal theory approximation CI = $\hat{N} \pm 1.96*SE(\hat{N})$.

LENGTH COMPOSITION

The length distributions of cutthroat trout ≥180 mm FL newly captured during the first event and

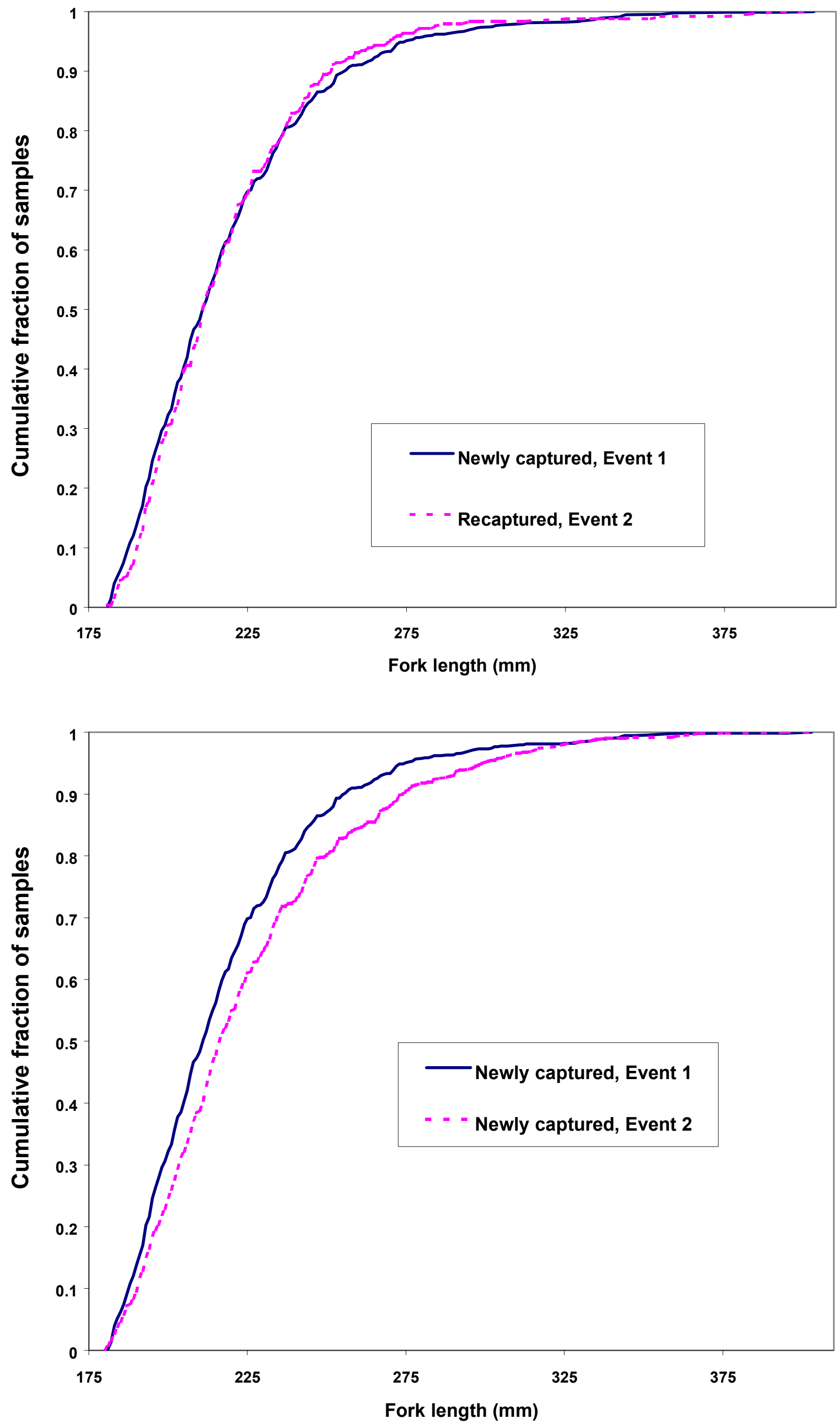

Figure 3.–Cumulative distributions of lengths of cutthroat trout newly marked in event 1 versus lengths of cutthroat trout recaptured in event 2 (top) **and newly captured during event 2** (bottom)**, Neck Lake, 1998.**

Table 5.–Number of cutthroat trout ≥180 mm FL recovered, by tagging and recovery area (m_{ij}), number marked by area (a_i), and number of unmarked captures by area during event 2 (u_j), Neck Lake, 1998.

Tagging area	Recovery area (m_{ij}) A	B	C	a_i
A	74	11	0	311
B	26	74	3	341
C	4	11	43	247
u_j	260	213	145	

Table 6.–Results of chi-square consistency tests for use of pooled Petersen model to estimate abundance, Neck Lake, 1998. Test for equal marked fractions in sampling event 2 by recovery area (top panel) and test for equal recovery rates for fish marked in event 1 by marking area (lower panel).

Recovery area	Number marked	Number unmarked	Fraction marked
A	104	260	0.29
B	96	213	0.31
C	46	145	0.24
χ^2 = 2.8, df = 2, P = 0.24; accept H_O			

Marking area	Marks recovered	Marks not recovered	Fraction recovered
A	85	226	0.27
B	103	238	0.30
C	58	189	0.23
χ^2 = 3.3, df = 2, P = 0.20; accept H_O			

newly captured during the second event (Figure 3, bottom panel) in 1998 were significantly different (KS test, D_{max} = 0.0977, P = 0.0016). Therefore, length data collected during the second event of 1998 were used to estimate length composition (Appendix A1). Length compositions of fish captured in 1996, 1997, and 1998 were quite similar (Figure 4).

During 1998, cutthroat trout ≥180 mm FL in Neck Lake were mostly (76%) <240 mm FL (Table 7). Ninety-three percent (93%) of the population in 1998 were <280 mm FL, and only 6% (52 of 864) of the cutthroat trout sampled during the second event were longer than the 12-inch minimum size limit (>287 mm FL) established for the sport fishery.

CATCH PER UNIT EFFORT

Catch per unit effort of cutthroat trout ≥180 mm FL caught with trap gear (Table 8) ranged from a high of 6.6 fish per trap in 1996 and 1998 to a low of 5.7 in 1997.

DATA FILES

Data collected during the study have been archived at ADF&G offices in Juneau and Anchorage (Appendix A4).

DISCUSSION

The 4-event JS model abundance estimate for mid-May 1998 of 2,742 (SE = 243) compares closely to the CP model estimate of 3,151 (SE = 144) for May 1998. Although the difference (409 fish) in estimates is not statistically different (2 sample z-test, P ≥ 0.4) it might arise as a result of some recruitment of larger (post-spawning) fish into the population between the first and second sampling events of 1998. Spawning migrations from small streams in a similar lake in Southeast Alaska were not completed until around the first of June (Harding 1995, Rosenkranz et al. 1999). We also note that while sampling in the CP experiment was not size selective (Figure 3, top panel), fish captured during the second sampling event were larger than fish captured two weeks earlier (Figure 3, lower panel). This may be due to immigration of larger fish from spawning streams, as we think it safe to assume that significant growth did not occur during the short sampling hiatus in May.

Possible explanations for the significantly lower probabilities of capturing a fish first marked in 1997 (relative to a fish marked in 1996 and seen

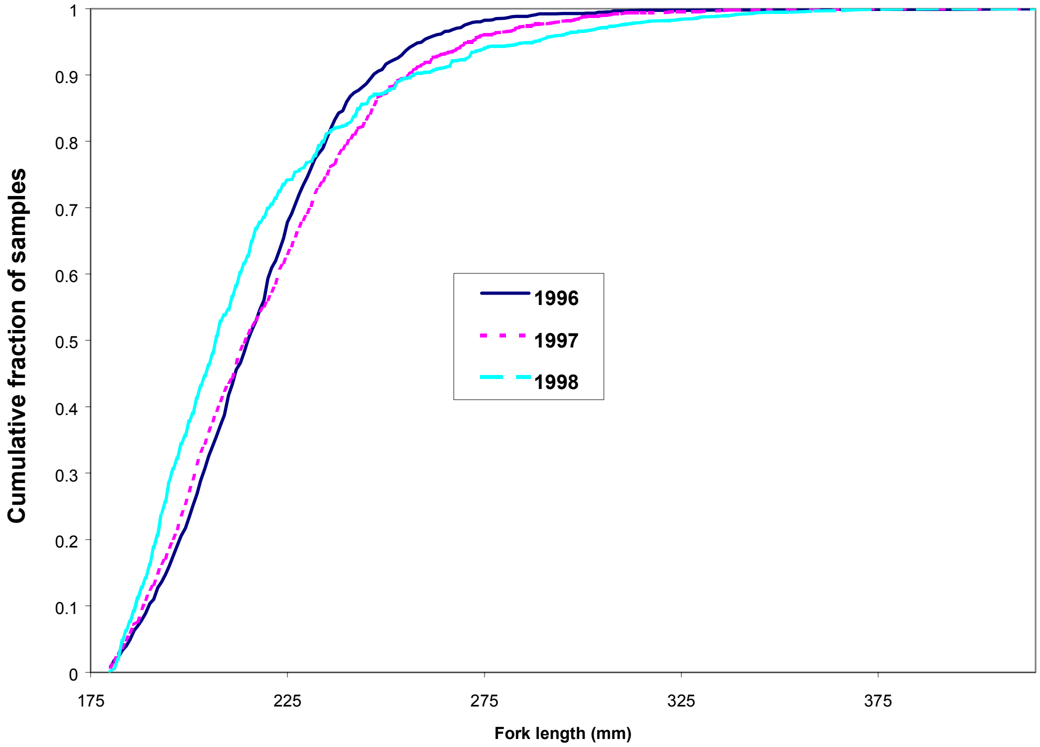

Figure 4.–Cumulative distributions of lengths of unique cutthroat trout captured during 1996 through 1998 annual sampling events at Neck Lake.

Table 7.–Length composition and estimated abundance at length for cutthroat trout ≥180 mm FL, Neck Lake, 1998. The sample size (n_a), proportion (p_a), abundance (N_a), standard error (SE), and coefficient of variation (CV) for each 20 mm length class are shown.

Length, (mm FL)	n_a	p_a	SE[p_a]	CV[p_a]	N_a	SE[N_a]	CV[N_a]
180 – 200	228	0.264	0.015	0.057	832	61	0.073
201 – 220	266	0.308	0.016	0.051	970	66	0.068
221 – 240	160	0.185	0.013	0.071	584	49	0.085
241 – 260	97	0.112	0.011	0.096	354	37	0.106
261 – 280	55	0.064	0.008	0.131	201	28	0.138
281 – 300	24	0.028	0.006	0.201	88	18	0.206
301 – 320	14	0.016	0.004	0.265	51	14	0.269
321 – 340	11	0.013	0.004	0.300	40	12	0.303
341 – 360	3	0.003	0.002	0.577	11	6	0.578
>360	6	0.007	0.003	0.407	22	9	0.409
Total	864				3,151		

Table 8.–Effort and catch statistics (top panel) **and catch per unit effort (CPUE,** lower panel**) for cutthroat trout (**CT**) and Dolly Varden (**DV**) captured in traps (fish/set) and with hook-and-line (**H&L, fish/hr**) at Neck Lake 1996–1998.**

	Effort		Catch					
			DV		CT <180 mm		CT ≥180 mm	
Year	No. traps[a]	H&L hrs	Trap	H&L	Trap	H&L	Trap	H&L
1996	251	36.1	2,134	0	380	19	1,646	94
1997	251	37.3	1,341	0	538	18	1,431	120
1998-1	130	18.0	1,580	0	200	4	851	64
1998-2	130	18.0	1,911	1	150	4	854	60
1998 total	260	36.0	3,491	1	350	8	1,705	124

	CPUE[b]					
	DV		CT <180 mm		CT ≥180 mm	
Year	Trap	H&L	Trap	H&L	Trap	H&L
1996	8.5	0.00	1.5	0.53	6.6	2.60
1997	5.3	0.00	2.1	0.48	5.7	3.22
1998-1	12.0	0.00	1.5	0.22	6.6	3.56
1998-2	14.7	0.06	1.2	0.22	6.6	3.33
1998 total	13.4	0.03	1.4	0.22	6.6	3.44

[a] Traps were generally fished overnight for approximately 18-30 hrs/set.

[b] Catch per overnight trap set or catch per hour of H&L.

again during 1997) (Table 2) include a higher natural mortality rate for smaller fish and short-term tag-induced mortality. A higher natural mortality rate for younger fish seems unlikely because younger fish are less likely to die from spawning than older fish, and because smaller fish did not appear to suffer a relatively high mortality rate in another lake in Southeast Alaska (Rosenkranz et al. 1999). In contrast, tag-induced mortality, which may be expressed largely in the smaller fish (compare statistics in Table 1), is plausible. Rosenkranz et al. (1999) concluded that a similar level (18-19%) of induced mortality was possible during studies at Florence Lake. Harding (1999) found that when tagging-related mortality did occur, smaller (e.g., 180-210 mm FL) cutthroat trout suffered significantly higher rates than did larger fish. Mortality is likely accelerated by high (17°C) water temperatures (Titus and Vanicek 1988, Schisler and Bergersen 1996, Harding 1999). Surface water temperatures at Neck Lake during sampling in 1996 varied between 14 and 16°C. In 1997, fish tagged during sampling at higher surface water temperatures (17 and 17.5°C) might have experienced increased mortality.

The effect of short-term tagging mortality is to bias the normal (full) JS-model estimate of abundance high. However, the generalized JS-model used in this analysis is unbiased for a one-period effect of handling and tagging. CP-model estimates would be biased high if the mortality occurred quickly, as one would suspect (e.g., Harding 1999). This provides another explanation for the small (15%) difference between the JS and CP abundance estimates for May 1998.

The annual survival statistic (ϕ = 0.51 SE = 0.06) from our analysis is the first unbiased estimate for a lake dwelling cutthroat population (fish ≥180 mm FL) in Southeast Alaska. Rosenkranz et al. (1999) and Freeman et al. (1999) provided estimates for Florence and Virginia Lakes but noted that, without exception, the estimates were biased. Similarly, Brookover et al. (1999) and Schmidt et al. (1998) report estimates for Sitkoh and Eva Lakes, but because anadromous populations use those lakes, their statistics may reflect emigration rates of some maturing (sea-run) fish as well as natural (and fishing) mortality.

One goal of the Neck Lake project was to investigate potential impacts from SSRAA's coho rearing project on the cutthroat trout population. Impacts of rearing coho salmon and opening of fish passes on previously landlocked populations of cutthroat trout have been studied at two locations in southern Southeast Alaska. An Alaskan steeppass was installed in Slippery Lake in 1988 which allowed anadromous fish to immigrate into the lake. Coho salmon fry were also stocked in the Slippery drainage between 1987 and 1990. Mean fork length of cutthroat trout captured in Slippery Lake declined from 205 mm in 1988 to 187 mm in 1990, but, the abundance of the lake population of cutthroat trout appeared unchanged (Wright et al. 1997).

A steeppass was also installed below Margaret Lake in 1990, and the lake was stocked with sockeye salmon fry from 1988 through 1994 and with summer-run coho salmon in 1991. Preliminary results of assessment studies indicate an inverse relationship of abundance between coho salmon and cutthroat trout; with the lower mean length of cutthroat trout suggesting a density dependent response to coho salmon (Bryant et al. 1994). While these studies do not identify any process or limiting factor(s), the competition appeared greatest between cutthroat trout <140 mm and coho salmon. Preliminary results also suggest that the invasion of anadromous salmonids has depressed naturally occurring cutthroat trout populations (Bryant et al. 1994).

Perhaps the best way to assess the cumulative impact of the coho rearing program (or lack of impact) to Neck Lake is to periodically estimate abundance and length-at-age of cutthroat trout in the lake. Scales collected in 1996–1998 at Neck Lake may be used in the future to estimate age and length-at-age of fish sampled in 1996–1998 (Table 9). Our scale collections also include small fish (some <100 mm FL) opportunistically collected in inlet streams and around the lake margins with baited traps.

The estimated length composition of cutthroat trout in Neck Lake revealed that few (6%) cutthroat trout were available for harvest under the current 12-inch minimum size limit. When this regulation was adopted by the Alaska Board

Table 9.–List of cutthroat trout scale samples collected at Neck Lake between 1996 and 1998 by year, location (lake or inlet stream), and size category.

Year	Length category (mm FL)	Number of samples: Lake	Inlet streams	Total
1996	<100	2	16	18
	100–139	25	6	31
	140–179	63	0	63
	180–219	166	0	166
	220–259	156	0	156
	260–299	57	0	57
	300–339	9	0	9
	>340	2	0	2
1997	<100	0	0	0
	100–139	0	0	0
	140–179	0	0	0
	180–219	675	0	675
	220–259	523	0	523
	260–299	94	0	94
	300–339	17	0	17
	>340	2	0	2
1998	<100	0	17	17
	100–139	1	20	21
	140–179	21	8	29
	180–219	216	0	216
	220–259	249	0	249
	260–299	120	0	120
	300–339	41	0	41
	>340	17	0	17

of Fisheries in 1994, it was established under the concept that a 12-inch minimum size limit would allow approximately 85% of the mature females to spawn at least once. However, this concept was developed from length at maturity data collected from sea-run fish in Petersburg Creek (ADF&G unpublished data), from landlocked populations in Mosquito Lake in the Queen Charlotte Islands, British Columbia (Leeuw 1987), and from trout populations in Washington and Oregon (Wright 1992). An extensive project was conducted throughout Southeast Alaska (including Neck Lake) during 1997 and 1998 to develop length at maturity data for Southeast Alaska cutthroat trout stocks. Based on these data, ADF&G has recommended that the regional minimum size limit for cutthroat trout be reduced from 12 to 11 inches. This change would increase the number of cutthroat trout legally available for harvest in Neck Lake to approximately 13% while still protecting the spawning population.

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APPENDIX A

Appendix A1.–Detection of size-selective sampling (from Bernard and Hansen 1992).

Result of Hypothesis Test on lengths of fish CAPTURED during the First Event and RECAPTURED during the Second Event	**Result** of Hypothesis Test on lengths of fish CAPTURED during the First Event and CAPTURED during the Second Event.

Case I: **Accept H_o** **Accept H_o**
There is no size-selectivity during either sampling event.

Case II: **Accept H_o** **Reject H_o**
There is no size-selectivity during the second sampling event but there is during the first.

Case III: **Reject H_o** **Accept H_o**
There is size-selectivity during both sampling events.

Case IV: **Reject H_o** **Reject H_o**
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A2.–Summary statistics for the Jolly-Seber model, Neck Lake.

Year	n_I	m_i	R_i	r_i	z_i
All fish ≥180 mm FL					
1996	1,625	0	1,625	377	0
1997	1,448	291	1,448	318	86
1998-1[a]	899	242	899	246	162
1998-2[a]	864	408	864	0	0
Fish 180-220 mm FL					
1996	965	0	965	249	0
1997	836	186	836	206	63
1998-1	655	167	655	188	102
1998-2	580	290	580	0	0
Fish >220 mm FL					
1996	660	0	660	128	0
1997	612	105	612	112	23
1998-1	244	75	244	58	60
1998-2	284	118	284	0	0

n_i= number of fish caught in sample *i.*

m_i=number of marked fish caught in sample *i.*

R_i=number returned to the population alive with marks from sample *i.*

r_i =number caught in sample *i* which are recaptured later.

z_i =number not caught in sample *i* which were previously captured and are recaptured later.

[a] 1998-1 = May 13-20, 1998; 1998-2 = May 29- June 7, 1998.

Appendix A3.–Capture histories for the Jolly-Seber model, Neck Lake.

	Frequency		
Capture history[a]	Fish 180-220 mm FL	Fish >220 mm FL	All fish ≥180 mm FL
1111	15	7	22
0111	30	11	41
1011	13	2	15
0011	130	38	168
1101	16	39	28
0101	61	12	100
1001	25	9	34
1110	25	5	30
0110	59	38	97
1010	25	12	37
1100	130	81	211
1000	716	532	1,248
0100	500	419	919
0010	358	131	489
0001	290	166	456

[a] A "0" signifies not captured during that particular sampling event while a "1" signifies a capture; i.e., a capture history of 1101 represents a group of fish that were captured during the 1st, 2nd and 4th sampling events and not captured during the 3rd event.

Appendix A4.–List of historical data and raw data files used to produce this report.

File name	Software	Contents
neck1996.xls	Excel	Trap and hook-and-line catches, tag numbers, lengths and sample numbers at Neck Lake in 1996.
neck1997.xls	Excel	Trap and hook-and-line catches, tag numbers, lengths and sample numbers at Neck Lake in 1997.
neck1998.xls	Excel	Trap and hook-and-line catches, tag numbers, lengths and sample numbers at Neck Lake in 1998.
Neck_js.xls	Excel	Sampling data and summaries used to produce estimates.