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Population Status of Summer Resident Cutthroat Trout at Sitkoh Lake, Southeast Alaska

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

FISHERY DATA SERIES NO. 99-30

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ABSTRACT

A lack of information about cutthroat trout *Oncorhynchus clarki* in Southeast Alaska prompted an examination of their population status in the Sitkoh Lake drainage on Chichagof Island. A study to estimate abundance and size composition in 1997 using a multi-season Jolly-Seber estimator was conducted from 1996 through 1998. The study was designed such that abundance was also estimated for 1997 using a two-event Petersen closed population estimator. An estimated 1,260 (SE = 221) cutthroat trout ≥180 mm were present in Sitkoh Lake and upper Sitkoh Creek in 1997 under the Jolly-Seber model, and 1,481 (SE = 262) fish were estimated in Sitkoh Lake with the Petersen model. Only 2 percent of the estimated cutthroat trout population were larger than the minimum 14-in total length limit (336 mm fork length) established for harvest in the sport fishery at Sitkoh Lake.

Key words: Alaska, Sitkoh Lake, cutthroat trout, abundance, mark-recapture, Petersen, Jolly-Seber, length composition, sea-run.

INTRODUCTION

Concern that cutthroat trout *Oncorhynchus clarki* and steelhead *O. mykiss* abundance was declining throughout Southeast Alaska prompted the Alaska Board of Fisheries to adopt more restrictive trout regulations in 1994. These regulations included general daily bag and possession limits for rainbow and cutthroat trout (in combination) of two fish between 12 and 22 inches total length (TL) and a ban on the use of bait in fresh water for most of the year. More restrictive regulations were also implemented in some waters. Prior to the regulation changes, daily bag and possession limits were 5 and 10 trout, including only 1 daily and 2 in possession over 16 in. TL, and the use of bait was allowed.

In Southeast Alaska, there are two main forms of cutthroat trout: freshwater resident and sea-run. Resident forms primarily inhabit landlocked lakes but are also found in some streams with barrier falls. Resident forms spend their entire life in fresh water. Sea-run cutthroat trout overwinter in lake systems open to saltwater access, migrate to salt water to feed in early spring and return to freshwater overwintering lakes in fall. Sea-run cutthroat trout populations have been enumerated by weir count for several Southeast Alaska systems open to salt water (Yanusz and Schmidt 1996, Jones and Harding 1998).

Cutthroat trout are also commonly found in open lake systems of Southeast Alaska during summer, after sea-run cutthroat trout have migrated. Whether these summer resident fish comprise immature anadromous or resident forms or, more likely, comprise a combination of both is unknown. Some of these fish migrate to salt water during some years but remain in fresh water during others (Lum et al. 1998). Studies conducted at Lake Eva (Yanusz and Schmidt 1996, Schmidt et al. 1998) provide the only previous attempts to estimate abundance and size composition of the summer resident component in a system with sea-run cutthroat trout. Summer resident components are important in many open lake systems in Southeast Alaska because much of the freshwater fishing effort occurs on these systems during the summer, after sea-run fish have emigrated.

In 1996, two studies were initiated by the Alaska Department of Fish and Game (ADF&G) to assess both the sea-run and summer resident populations of cutthroat trout in the Sitkoh Lake drainage. The first project estimated the abundance of sea-run cutthroat trout in the Sitkoh Lake drainage by installing a weir on the outlet stream, and in 1996, 3,955 cutthroat trout emigrated from the system (Yanusz 1997). The objective of this (second) project was to estimate the abundance and length composition of cutthroat trout ≥180 mm fork length (FL) present in Sitkoh Lake and the upper section of Sitkoh Creek during late June when mature sea-run cutthroat trout are absent. Sampling in 1996, 1997 and 1998 allowed us to estimate abundance and length composition in 1997 using an open population model, and two-event sampling in 1997 allowed us to estimate abundance in 1997 using a closed population model. The two estimates would, we reasoned, provide a robust analysis of population size at Sitkoh Lake and upper Sitkoh Creek during late June.

STUDY AREA

The Sitkoh Lake drainage is located on southeastern Chichagof Island in Southeast Alaska (Figure 1), and empties into Chatham Strait via Sitkoh Bay (57°31′11″ N. lat., 134°57′30″ W. long.). Sitkoh Lake (ADF&G Anadromous Stream Catalog No. 113-59-10040-0010) has a surface area of 189 ha and a maximum depth of 42 m, with an elevation of approximately 59 m (Figure 2). Sitkoh Creek (ADF&G Anadromous Stream Catalog No. 113-59-10040) is about 6.4 km long, 10 to 30 m wide, and up to 3 m deep.

The Sitkoh Lake system is widely known for its freshwater fisheries for cutthroat trout and Dolly Varden *Salvelinus malma*, and supports one of the largest spawning populations of steelhead in northern Southeast Alaska (Jones 1983). The U.S. Forest Service (USFS) maintains two popular public-use cabins on Sitkoh Lake, and the area is accessible by floatplane and boat from Sitka and Juneau. The system is an important overwintering site for anadromous Dolly Varden and cutthroat trout (Yanusz 1997). ADF&G staff observations during steelhead snorkel surveys indicated that upper Sitkoh Creek contained a high density of cutthroat trout (A. E. Schmidt, J. D. Jones, Alaska Department of Fish and Game, Douglas, personal communication). Despite the popularity and accessibility of the Sitkoh system, its populations of cutthroat trout had last been studied in the 1930s (Banta *Unpublished*; Chipperfield *Unpublished*).

The Sitkoh Lake system receives the third highest level of freshwater sport fishing effort in the Sitka area, exceeded only by Baranof Lake and Lake Eva (A. L. Howe, Alaska Department of Fish and Game, Anchorage, personal communication). The majority of sport fishing effort occurs between May and August, and much of the angling effort is focused in upper Sitkoh Creek. Recent annual harvest estimates for cutthroat trout range from 55 to 647 fish and exceed harvests of any other species in the drainage; catch estimates for cutthroat trout range from 447 to 3,487 (Appendix A1). In 1994, Sitkoh Lake was designated a "high use" lake where bait was prohibited year-round and the daily bag and possession limits were two trout between 14 and 22 inches TL. However, Sitkoh Creek remained under regional regulations, with daily bag and possession limits of two trout between 12 and 22 in. TL and use of bait allowed from September 15 through November 15.

METHODS

Two mark-recapture experiments were used to estimate the abundance of cutthroat trout ≥180 mm FL in the Sitkoh Lake drainage during early summer 1997. A 3-year (1996–1998) Jolly-Seber (JS) open population experiment was conducted to estimate abundance in Sitkoh Lake and upper Sitkoh Creek, and a 1-year (1997) Petersen closed population (CP) experiment was conducted to estimate abundance in Sitkoh Lake only. Sampling for the JS experiment began in mid-June from 1996 through 1998 when emigration of mature, anadromous cutthroat trout was assumed to be nearly complete. Sampling occurred during June 15–23, 1996 (event 1) and June 17–26, 1998 (event 3). Sampling in 1997 occurred during two 7-day sampling trips between June 17 and July 3 with a 4-day hiatus, to estimate abundance with the CP model. Sampling in 1997 was pooled into event 2 for use in the JS model.

The lake was divided into three sections of roughly equal size (Figure 2) to facilitate sampling, data recording, and evaluation of the experimental assumptions. The three sampling areas were further divided into eight sections each (24 total) so that daily sampling would proceed systematically from one end of the lake to the other and to ensure that all fish had an equal probability of capture. Depths greater than 35 m were not sampled because very few fish have been found below 35 m in other studies (Benson 1961).

During each sampling trip, 24 baited traps were randomly moved each day through the 24 lake sections so that the total amount of gear set was uniformly distributed across all areas of the lake less than 35 m in depth. Immediately prior to resetting traps, placement was determined by randomly selecting a point within each section on a map of the lake. Traps were set overnight on the lake bottom and trap depths were measured with a fathometer. In addition, hook-and-line sampling was conducted by casting or trolling a variety of small lures (spinners, small spoons and other artificial lures) from a boat as it traversed the lake perimeter.

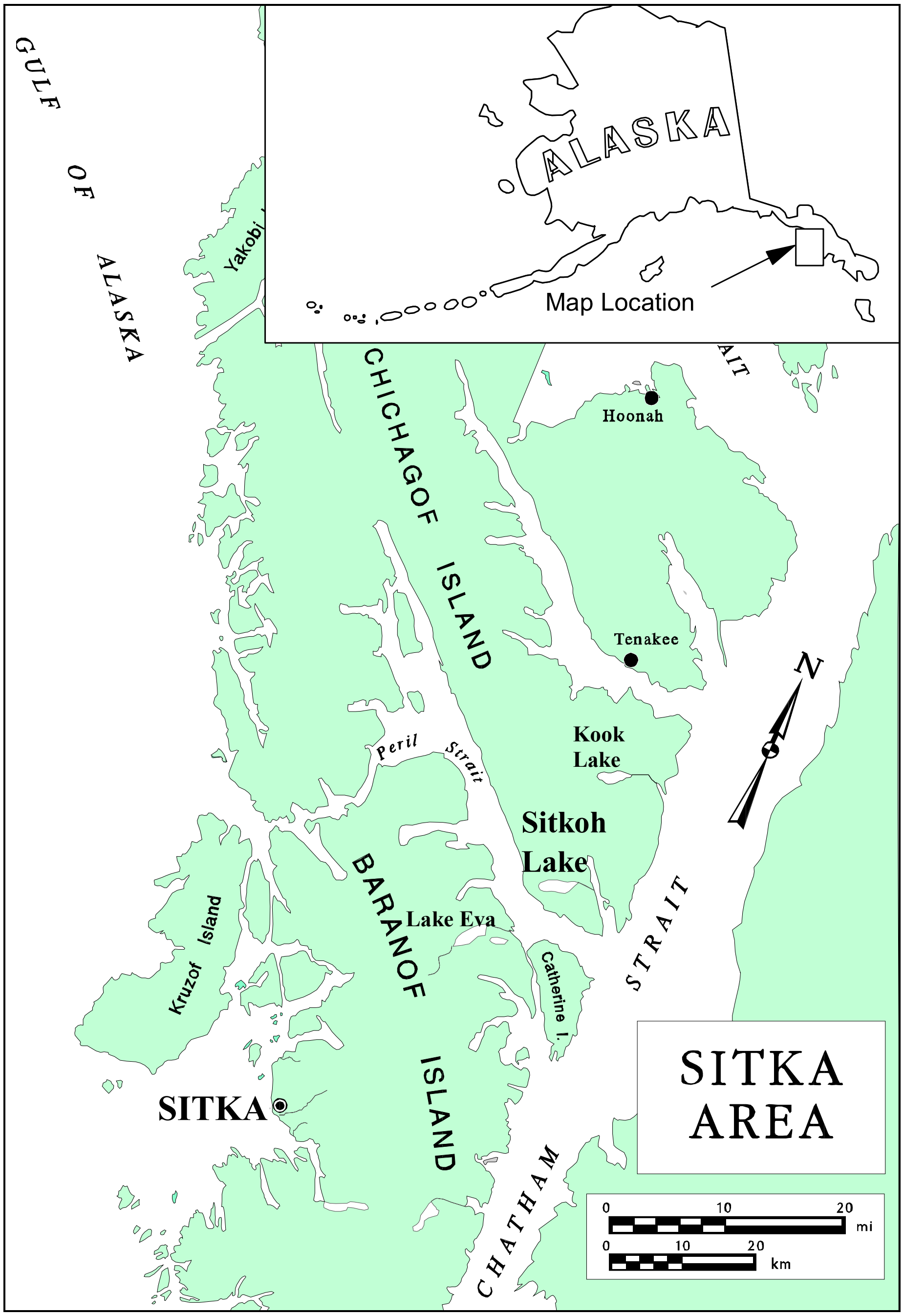

Figure 1.–Sitka area and location of Sitkoh Lake in Southeast Alaska.

The upper 1 km of Sitkoh Creek was included as a (fourth) sampling area, because ADF&G staff observed high densities of cutthroat trout in upper Sitkoh Creek and much of the angling effort is focused there. We divided Upper Sitkoh Creek into two sections of equal length and distributed sampling effort equally between each section. Sampling with hook-and-line was conducted over a 3-day period by a 2- or 3-person crew each season. Sampling with two baited traps was also conducted in Sitkoh Creek in 1996 but was subsequently discontinued due to low catch rates.

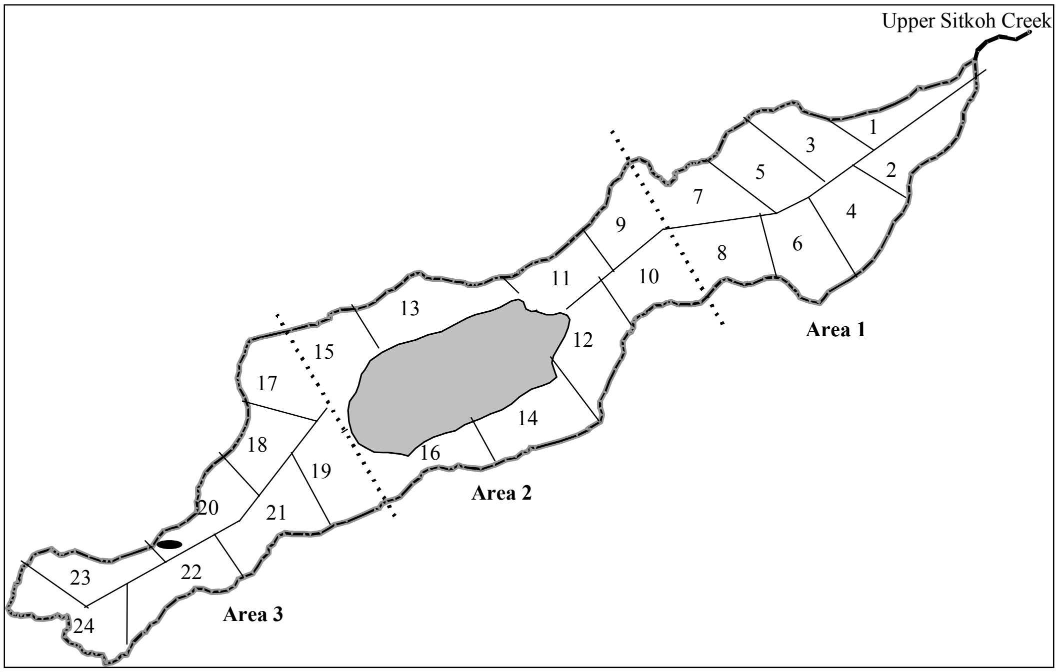

Figure 2.–Study map showing Sitkoh Lake sampling areas. Shaded area indicates lake depth >35 m.

In 1997, hook and line sampling was conducted for one day in Sitkoh Creek, from 1 km downstream of the lake outlet to the estuary, in order to investigate whether tagged fish had emigrated from the study area. Given the limited sampling effort, results of this sampling served only as a positive indicator of emigration if tagged fish were captured.

Funnel traps 1 m long and 0.6 m wide with a single opening at each end were constructed with two metal hoops and ¼-inch Vexar mesh. About 300 ml of salmon eggs, disinfected in a 1% Betadine solution for 15 minutes and cured with Borax, were suspended in a perforated bait container within each trap.

All captured cutthroat trout ≥180 mm FL 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, sampled for scales 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 right ventral fin and axillary process in 1996, clipped left ventral fin and axillary process in 1997, and a dorsal punch in 1998; scales were removed from the caudal peduncle directly above the lateral line. Cutthroat trout <180 mm FL, rainbow trout, steelhead, Dolly Varden and coho salmon *O. kisutch* captured were counted and released.

ESTIMATION OF ABUNDANCE IN 1997 UNDER THE CP MODEL

Data for the first (marking) event of the CP model were collected during a sampling trip conducted from June 17 to June 23. Following a 4-day hiatus, a second (recapture) event was conducted between June 28 and July 3. Both sampling events were limited to Sitkoh Lake only.

Assumptions to be met for the CP single mark-release experiment are:

(a) the population is closed; i.e., recruitment (or immigration) and death (or emigration) do not both occur between sampling events;

(b) every fish has an equal probability of being marked during the first event, or every fish has an equal probability of being sampled during the second event, or marked and unmarked fish mix completely between events;

(c) marking does not affect the catchability of a fish; and

(d) fish do not lose marks between events, and marks are recognized and reported.

Although there is no formal test for closure in a two-event experiment, we feel the closed population assumption is reasonable, as no significant natural mortality or growth recruitment was expected during the relatively short duration of the experiment (16 days).

We tested the second assumption with respect to space (lake area) and fish size. The assumption that marked fish were recovered with equal probability in each part of the lake was evaluated with contingency table analysis by testing if, given some mixing between areas, marked fish were recaptured with equal probability in each of the three sampling areas during the recovery event. If we failed to reject this hypothesis, a simple Petersen model would be used to estimate abundance; if not, a stratified estimator (Darroch 1961; Seber 1982, Chapter 11) would be used. Size-selectivity was tested with two Kolmogorov-Smirnov (KS) tests. If size-selective sampling were apparent in the recovery event data, stratification by size group would be evaluated (Appendix B1).

We cannot test for effects of marking on catchability with only two sampling events. Evidence of tag loss and tagging stress was recorded for every fish handled. Because all tagged fish were given a permanent secondary mark (a finclip), tag loss was measured and could be accounted for in the estimates.

ESTIMATION OF ABUNDANCE IN 1997 UNDER THE JS MODEL

In 1998 (after the third sampling event), the abundance of cutthroat trout in Sitkoh Lake and upper Sitkoh Creek was estimated using an open capture-recapture JS model. The program JOLLY (see Pollock et al. 1990 for a description of JOLLY) was used to determine which JS model best fit the data and to estimate abundance.

The assumptions necessary for accurate estimation of abundance with the generalized JS model are as follows (Seber 1982):

(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 was negligible).

The assumption of equal probability of capture during all capture events involved evaluating selectivity caused by sampling location, gear and fish length. Chi-square tests were used to test the assumption of equal probability of recapture between gear types and sampling locations. Contingency tables were also examined to detect mixing between gear types and sampling locations. Kolmogorov-Smirnov tests were used to determine if the length distribution of the recaptured fish was the same as the length distribution of the marked fish. Within a sampling event, the length distribution of fish that were later recaptured was compared to the length distribution of all fish marked during that event.

Contingency table chi-square tests developed by Pollock et al. (1985) as implemented in JOLLY were used to evaluate the goodness-of-fit of the JS model. The first portion of the two-component test tested for short-term mortality due to tagging and helped detect lowered survival rates due to tagging or the trapping and handling process (Arnason and Mills 1987). The second test component was used to detect heterogeneity of survival and capture probabilities. A summation of the chi-squares from each component forms an omnibus test for violations of assumptions 1 and 2 listed above.

Assumption 3 was evaluated by direct examination of mortality from each event.

Assumption 4 was addressed by double marking trout with a secondary mark.

We think assumption 5 was met, because within-year sampling was limited to 10 days. During the

10 day span, additions and losses to and from (including temporary immigration and emigration) the population should be negligible.

Because the goal of the mark-recapture experiment was to estimate the size of the cutthroat trout population (including immature anadromous fish) residing in the lake and upper creek where most fishing occurs, each annual sampling event needed to occur when mature anadromous fish are out of the system. Historical data for Lake Eva (Armstrong 1971, Schmidt et al. 1998) and Sitkoh Creek (Yanusz 1997) suggested that emigration of sea-run fish was nearly complete, and immigration of sea-run fish was barely starting, during our sampling periods. Post-spawning resident trout were also expected to be present during our study, as spawning is largely completed by mid-June (Armstrong 1971, Morrow 1980, Trotter 1987, Behnke 1992).

Fish movements at the Sitkoh weir (Yanusz 1997) may not accurately indicate movements in and out of our study area (lake and upper creek). However, it probably takes some time for fish to move through the long (5.5 km) reach between the Sitkoh weir and our study area, so movements at the weir would overstate movements in and out of the study area during the sampling period. In 1996, no trout tagged in the study area were caught at the weir, which was removed June 29. During 1997 and 1998 we were able to determine mixing of tagged fish from 1996 and 1997 between the lake and creek.

Length Composition

The proportion of the population in 1997 in length class j and its variance were estimated as a binomial proportion (Cochran 1977) by

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

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

where

n_j = the number of cutthroat trout of length class j, and

n = the total number of cutthroat trout sampled for length.

The abundance in 1997 of cutthroat trout by length class was estimated as a product of two random variables by

$$\hat{N}_j = \hat{N}\,\hat{p}_j \tag{3}$$

And its variance by (Goodman 1960):

$$Var(\hat{N}_j) = \hat{N}^2 Var(\hat{p}_j) + \hat{p}_j^{\,2} Var(\hat{N}) - Var(\hat{p}_j) Var(\hat{N}) \tag{4}$$

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.

Final data files (Appendix C1) are archived at Sport Fish Division Policy and Technical Services.

RESULTS

Abundance in 1997 under the CP Model

The estimated abundance in 1997 of cutthroat trout ≥180 mm FL in Sitkoh Lake was 1,481 (SE = 264). During the first sampling event, 162 cutthroat trout ≥180 mm FL were marked and released alive. During the second sampling event 208 unique cutthroat trout ≥180 mm FL were examined, and 22 of these had been marked during the first event. No tag loss was observed. There was no correlation between CPUE and depth (r = 0.07).

The length distributions of cutthroat trout captured during the first event and recaptured during the second event were not significantly different (KS test, D_{max} = 0.16, P = 0.85, Figure 3). There was a significant difference in the length distributions of cutthroat trout captured during the first event and those captured during the second event (KS test, D_{max} = 0.19, P <0.01). These results indicate that there may have been size-selectivity during the first event. However, the uniform change in

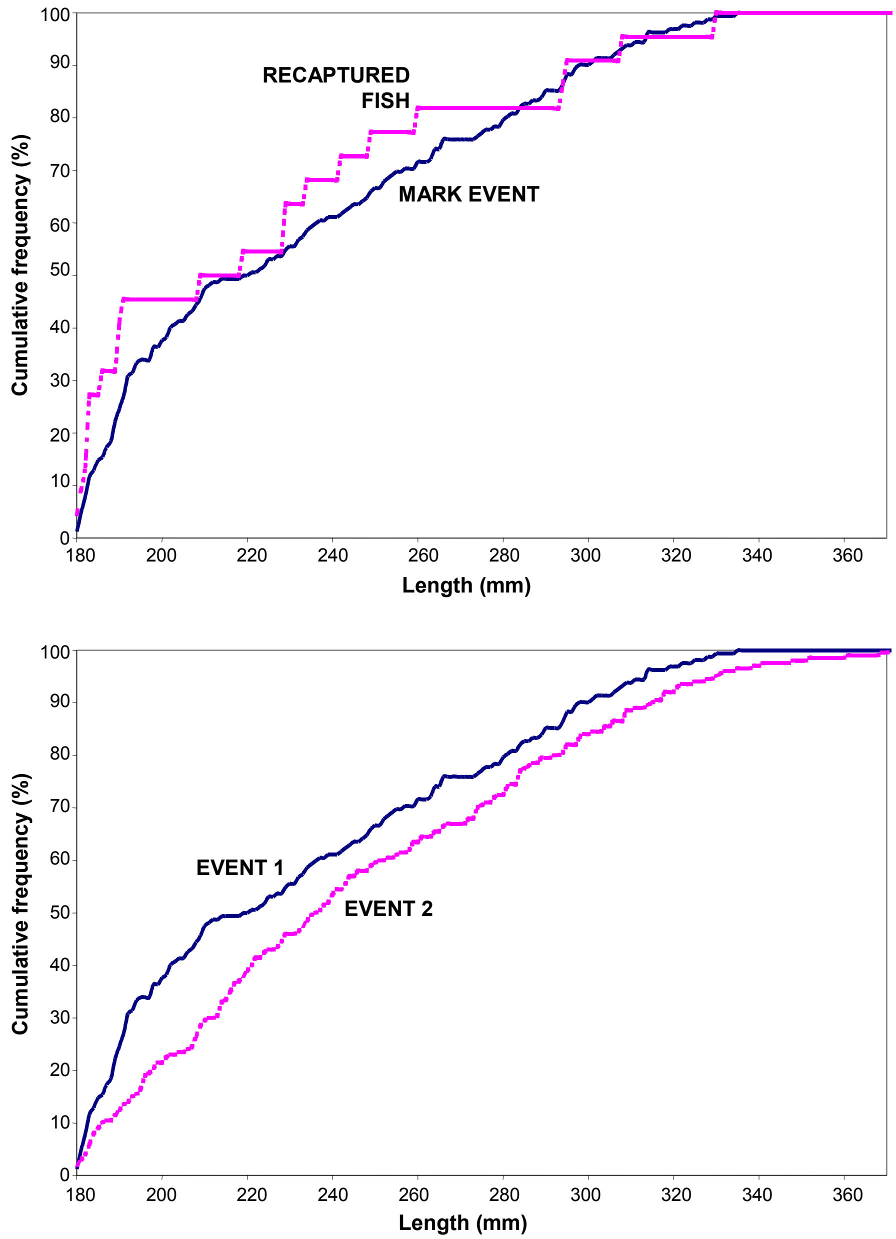

Figure 3.–Cumulative distributions of lengths of cutthroat trout marked in event 1 versus lengths of cutthroat trout recaptured in event 2 (top) **and examined during event 2** (bottom)**, Sitkoh Lake, 1997.**

the size distributions suggests that growth, rather than size-selective sampling, might be responsible for the observed differences. Because there was no size-selectivity during the second event, an unstratified abundance estimator was used.

The probability of recapture was not significantly different among the different areas of the lake ($\chi^2 = 4.56$, P = 0.10, Table 1), and 41% of the recaptured fish were recaptured outside the area where they were marked. These two results indicate that mixing was sufficient to minimize bias in the estimate.

The probability of recapture was not significantly different between gear types ($\chi^2 = 3.74$, P = 0.06,

Table 1.–Probability of recapture of cutthroat trout in Sitkoh Lake by location (one of the tests of assumptions needed for the closed population abundance estimator).

Study area	Recaptured		Total	Probability of recapture	χ^2	p-value
	No	Yes				
1	102	6	108	0.08	4.56	0.10
2	40	9	49	0.18		
3	44	7	51	0.13		
Total	186	22	208			

Table 2) and 18% of the recaptured fish were recaptured with a gear type different from the gear used during the marking event. These two results indicate that there was no need to stratify by gear type and both gear types can be used in the abundance estimate.

During the hiatus, 100 cutthroat trout ≥180 mm FL were tagged in upper Sitkoh Creek. None of the fish tagged in the creek were recaptured in the lake and none of the fish marked in the lake were captured in the creek. This suggests that mixing is negligible between the lake and the creek for the short duration of the CP experiment.

Fifty-eight (58) cutthroat trout, including one that had been tagged at the weir in 1996, were captured over 10.7 rod-hours expended in lower Sitkoh Creek below the study area in 1997. No fish were captured that had been tagged in the lake or upper creek during 1996 or 1997.

Table 2.–Probability of recapture of cutthroat trout in Sitkoh Lake by gear type.

Gear type	Recaptured		Total	Probability of recapture	χ^2	p-value
	No	Yes				
Hook and line	73	4	77	0.05	3.74	0.06
Funnel trap	113	18	131	0.13		
Total	186	22	208			

ABUNDANCE IN 1997 UNDER THE JS MODEL

During the three years of the study a total of 1,182 cutthroat trout ≥180 mm were captured (Table 3). Within this, 1,104 unique cutthroat trout were captured at least once during a sampling event, 71 were sampled during 2 different sampling events and 3 were handled in all three sampling events. Tag loss was estimated to be 1.2% (6 fish were recaptured in 1998 with missing tags).

Table 3.–Capture history of cutthroat trout in Sitkoh Lake and upper Sitkoh Creek.

	Event			Totals
	1996	1997	1998	
Captured	367	451	364	1,182
Unmarked	367	421	316	1,104
Recaptured	0	30	48	78
Originally marked in 1996	0	30	13	43
Originally marked in 1997			35	35
Sampling mortalities	0	2	1	3

Almost all (94%) of the fish caught in the creek were caught with hook and line gear. The amount of sampling effort spent in the creek varied between years. The chi-square test of the assumption of equal probability of recapture between fish tagged in the lake and those tagged in the creek was rejected, indicating the need for separate estimates for the lake and creek (Table 4). Only 4 fish tagged in the creek were later recaptured. Because the number of recaptures of fish originally tagged in the creek was so small (4), it was necessary to limit the data to fish caught in the lake only. However, the abundance estimate is relative to both the lake and the creek, because there was mixing between the creek and the lake between years.

Table 4.–Probability of recapture and mixing of cutthroat trout in Sitkoh Lake and upper Sitkoh Creek by location.

Marking location	Total marked	Recaptured?		No. of recaptures by location		Probability of recapture	χ^2	p-value
		No	Yes	Creek	Lake			
Creek	169	165	4	1	3	0.024	11.815	0.001
Lake	621	553	68	6	62	0.109		
Total	790	718	72	7	65			

When only the lake data are used, the chi-square test of the assumption of equal probability of recapture between gear types is also rejected (Table 5). Because we recaptured only 4 fish originally tagged with hook and line gear, we estimated abundance using only data from cutthroat trout caught with funnel traps. However, mixing was demonstrated between gear types. We determined that no size selectivity occurred, because the length distributions of fish caught among years were not significantly different (lake and funnel traps only, Anderson-Darling test, Takn = 1.25, P = 0.11, Figure 4). Therefore, the data used to estimate the abundance of cutthroat trout were not stratified by size, were limited to the lake only, not including the creek, and were based on those fish captured with funnel traps (Table 6). The abundance estimate is relative to the lake and at least part of the creek because there was mixing between the two areas.

Data were insufficient to evaluate the goodness-of-fit of the JS model A which allows for both death and immigration. Model D, which is the JS model with both survival rate and capture probability assumed constant per unit time, appeared to fit the data best. The estimated abundance of summer resident cutthroat trout ≥180 mm in Sitkoh Lake and upper Sitkoh Creek during 1997 was 1,260 (SE = 221, Table 7). Estimated survival of marked fish was 0.43 (SE = 0.06).

We recaptured 16 cutthroat trout that had been tagged at the weir in 1996. Of those originally marked at the weir, 2 were recovered in the lake or creek in 1996, 13 in 1997, and one in both 1997 and 1998.

LENGTH COMPOSITION

Fish captured with hook and line (mean FL = 270 mm, SE = 3) were larger than fish captured with traps (mean FL = 232 mm, SE = 2) (Figure 5). Because mixing was demonstrated between gear types in 1997, we pooled all sampling data from 1997 to estimate length composition of the population.

Length composition of cutthroat trout ≥180 mm FL in Sitkoh Lake and upper Sitkoh Creek consisted mainly (55%) of fish <240 mm FL (Table 8). Eighty-six percent (86%) of the population in

Table 5.–Probability of recapture and mixing of cutthroat trout in Sitkoh Lake by gear type.

Capture gear	Total marked	Recaptured?		Recapture gear		Probability of recapture	χ^2	p-value
		No	Yes	Hook and line	Funnel trap			
Hook and line	130	126	4	2	2	0.031	8.922	0.003
Funnel trap	485	427	58	10	48	0.119		
Total	615	553	62	12	50			

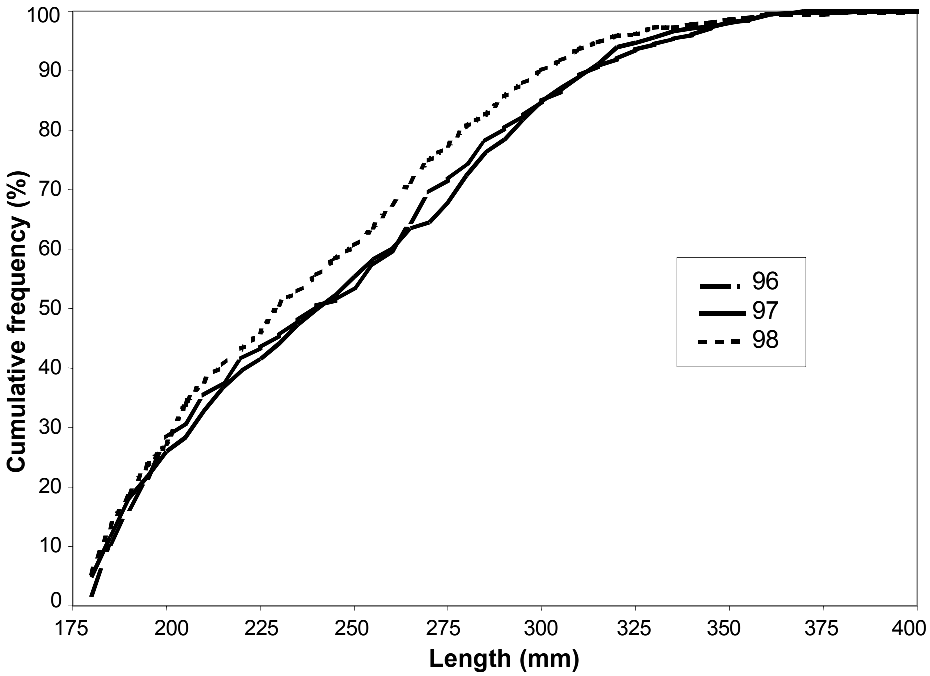

Figure 4.–Cumulative distributions of lengths of cutthroat trout captured with funnel traps in Sitkoh Lake, 1996–1998.

Table 6.–Capture history of cutthroat trout caught with funnel traps in Sitkoh Lake.

	Event			
	1996	1997	1998	Totals
Captured	261	254	292	807
Unmarked	261	236	257	754
Recaptured	0	18	35	53
Originally marked in 1996	0	18	8	26
Originally marked in 1997			27	27
Sampling mortalities	0	2	1	1

1997 was <300 mm FL. Based on a relationship reported by Harding and Jones (1993), a TL of 14 in. corresponds to a FL of 336 mm, and therefore only 11 (2%) of the 533 cutthroat sampled had a TL greater than the 14-in. minimum size limit in the lake.

CATCH PER UNIT EFFORT

Catch per unit effort of cutthroat trout ≥180 mm FL caught with trap gear (Table 9) ranged from a high of 0.07 fish per hour in 1996 to a low of 0.04 in 1997. The annual CPUE should be comparable since trapping methods remained consistent. Although trapping occurred in the creek in 1996 and not 1997 or 1998, impacts to the overall CPUE should be minimal considering the small number of traps (2) used. CPUE for hook and line gear varies less between years.

DISCUSSION

The CP model estimated the abundance of cutthroat trout in 1997, in the lake only, to be 1,481 (SE = 262) while the JS model, for the same time period, estimated the abundance in the lake and the upper creek to be 1,260 (SE = 221). The estimates would not be considered significantly different unless the population in the upper creek were greater than 470 cutthroat trout—which is the minimum detectable difference for a 2-sample

Table 7.–Population estimates for cutthroat trout in Sitkoh Lake and upper Sitkoh Creek using Jolly-Seber Model D.

Parameter	Period	Estimate	SE	95% confidence interval
Survival:				
	constant	0.43	0.06	0.32–0.55
Capture probability:				
	constant	0.20	0.03	0.14–0.27
Abundance:				
	1997	1,260	221	827–1,694
	1998	1,441	255	942–1,940
	Mean	1,351	329	706–1,995
Recruitment:				
	1997	868	113	646–1,090

Z-test with the probabilities of type I and type II error at 0.05 and 0.20, respectively (Zar 1984). One hundred (100) cutthroat trout were captured in the upper creek in 1997, indicating a sizeable population there. However, limited area and focused sampling effort in the creek would tend to increase catchability. A visual survey of the upper creek on July 1, 1997 (6 days after sampling was completed in the upper creek) under good conditions yielded roughly equal numbers of tagged and untagged cutthroat trout. Although a few tags observed may have been applied in the lake or at the weir, most were likely applied in the creek, and it is likely the upper creek population was less than 470 fish.

Other studies have also compared closed and open population estimates for cutthroat trout in Southeast Alaska lakes. Rosenkranz et al. (1999) found that estimates for Florence Lake from both types of models were very similar in 1994 when data collection was begun prior to the spawning season, however, when sampling occurred during spawning or when the lake was not fully sampled, the estimates were very different. Yanusz and Schmidt (1996) used a closed population model to estimate 2,154 (SE = 274) cutthroat trout ≥180 mm FL in Lake Eva in 1995 and, subsequently, an open population model was used to estimate 1,487 (SE = 464) for the same system in 1996 (Schmidt et al. 1998). Although pertaining to different years, the estimates are not statistically different, and the results from the two types of models are similar to those from this study. The annual survival rate of 0.43 (SE = 0.06) for our study was substantially higher than unusually low annual survival rates (0.27, SE = 0.07) estimated at Lake Eva (Schmidt et al. 1998). The survival rate of 0.43 appears to be more typical of estimates at other lakes such as Florence Lake, where annual survival estimates from their 4-event version of the JS experiment ranged from 0.40 to 0.52 (Rosenkranz et al. 1999). Although our estimate of recruitment into the 1997 population (868 fish, or 64% of the abundance estimate) may seem unusually high, it is supported by the large component of small fish in the lake population.

The recapture of cutthroat trout originally tagged at the weir established that the population of cutthroat trout in the lake and creek during the sampling period included some sea-run fish. Since the weir was not operated after 1996, the rate of anadromy for cutthroat trout and, more germane to this study, the portion of the summer population that never enters the sea, remains unknown.

Operation of the weir in 1996 established that trout tagged in the upper creek and lake did not emigrate to salt water during the 1996 marking period. The two fish originally tagged at the weir and recaptured in the upper creek in 1996 had obviously completed their saltwater migration prior to the 1996 sampling period. Four of the 16 fish tagged at the weir and later recaptured in the upper creek or lake had emigrated past the weir after June 17, the latest that sampling began in the upper creek and lake. While these findings help define the likelihood of immigration/ emigration during the study period, the rate of occurrence was so low that effects on either abundance estimate caused by migration to salt water during the study period are probably negligible.

The low recapture rate (Table 5) for cutthroat trout originally captured with hook and line was

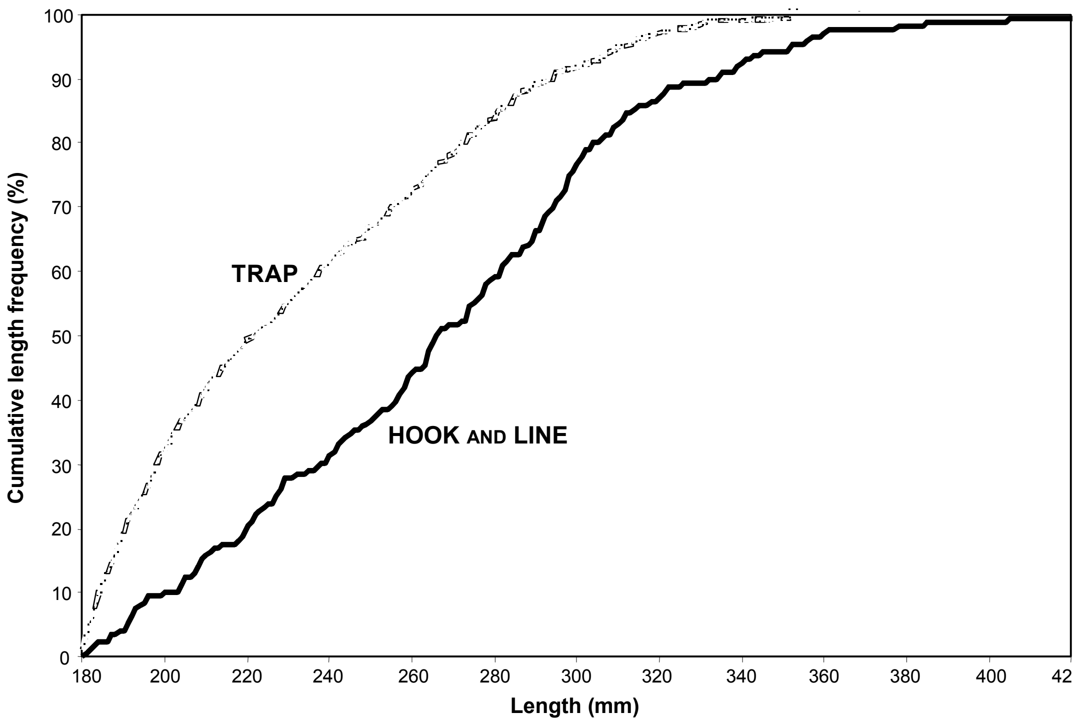

Figure 5.–Cumulative distributions of lengths of cutthroat trout captured with funnel traps and hook and line in Sitkoh Lake and upper Sitkoh Creek, 1996–1998.

Table 8.–Estimated length composition of cutthroat trout ≥180 mm FL in Sitkoh Lake and upper Sitkoh Creek in mid-June 1997.

Length category (mm)	Sample size n_j	Proportion $\hat{p}_j$	$SE(\hat{p}_j)$	Estimated abundance $\hat{N}_j$	$SE(\hat{N}_j)$
180–199	95	0.27	0.02	341	67
200–219	54	0.15	0.02	194	42
220–239	44	0.13	0.02	159	36
240–259	37	0.11	0.02	134	31
260–279	32	0.09	0.02	115	28
280–299	41	0.12	0.02	147	34
300–319	27	0.08	0.01	97	25
320–339	14	0.04	0.01	50	16
340–359	3	0.01	0.01	11	7
360–379	3	0.01	0.01	11	7
Total	533	1.00		1,260	

Table 9.–Trap and hook and line (H&L) effort, catch, and catch per unit effort (CPUE) for cutthroat trout and Dolly Varden in Sitkoh Lake, 1996–1998.

			Catch			**CPUE**		
		Effort	Dolly	Cutthroat trout		Dolly	Cutthroat trout	
Year	**Gear**	(hours)	Varden	<180mm	≥180mm	Varden	<180mm	≥180mm
1996	Trap	4,040	66	220	281	0.02	0.05	0.07
	H&L	77	0	8	100	–	0.10	1.29
1997	Trap	6,527	113	270	271	0.02	0.04	0.04
	H&L	156	1	44	222	0.01	0.28	1.42
1998	Trap	5,494	141	268	327	0.03	0.05	0.06
	H&L	75	0	18	84	–	0.24	1.12

difficult to assess. At McKinney Lake (Harding et al. *In press*), marked fractions of cutthroat trout captured along the shoreline (where most hook and line effort was expended) were significantly lower than marked fractions of cutthroat trout captured along the lake bottom (where baited funnel traps were set). They believed the difference in probability of recapture in McKinney Lake was because hook and line was less effective at capturing cutthroat trout than baited funnel traps and that mixing between areas was incomplete. If mixing is incomplete between shallow and deep areas of Sitkoh Lake, the low recapture rate for cutthroat trout originally captured with hook and line may indicate a larger density of fish in shallow water, but this would not bias the JS estimate because traps were fished in shallow as well as deep water. It is also possible that there was higher hooking or tagging mortality associated with either hook and line gear or larger fish. If fish tagged using hook and line were more likely to die, the population estimate produced by the CP model may be positively biased. Since the JS model estimate only used fish caught in hoop traps, the open population estimate would not be similarly biased. In fact, since fish caught by hook and line were larger than those caught in traps (Figure 5), it is possible that the JS estimate was negatively biased because a portion of the population (very large fish >320 mm) were not easily captured in hoop traps. Unfortunately, it remains uncertain whether large fish were underrepresented, thereby biasing abundance and size composition estimates.

The estimated abundance of cutthroat trout ≥180 mm FL in the lake and upper creek during 1997 was approximately one-third the abundance of sea-run cutthroat trout emigrants in 1996 (3,955). The 1996 weir emigration was the largest observed for this system and trout which reside for the summer in the lower 4.5 km of creek below our study area and in tributaries to the lake were not included in this study. Therefore, the summer resident and sea-run populations are probably more similar in size.

The component of the summer resident population (2%) larger than the 14-in. minimum size limit in Sitkoh Lake and, therefore available for harvest, is much smaller than the 23% of the sea-run population (R. J. Yanusz, Alaska Department of Fish and Game, Juneau, personal communication). Because so few summer resident cutthroat trout were of legal retention size, the fish residing in the lake do not appear vulnerable to over-exploitation. However, because mixing does occur between the lake and the upper creek, where a minimum size limit of 12 in. applies and much of the angling takes place, up to 20% of the summer resident population is legally harvestable if they move into the creek. Given low post-1994 annual harvests (<200 fish) on mixed populations of sea-run and summer resident cutthroat trout and high recruitment into the summer resident population, current regulations appear adequate to sustain the population of cutthroat trout present in the Sitkoh Lake system during summer. The risk of damage to the summer population by excessive harvest of cutthroat trout >12 in. from the creek is low, because of low harvest rates on that population. Should annual harvests increase beyond current levels, further protection, such as a drainage-wide size limit of 14 inches, may be necessary.

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APPENDICES

Appendix A1.–Estimated angler effort and cutthroat trout harvest and catch in the Sitkoh Lake system, 1990–1997.

Year	Days fished	Cutthroat harvest	Cutthroat catch	No. of survey respondents
1990	694	375	1,345	20
1991[a]	795	55	447	12
1992	437	229	2,447	14
1993	1,627	647	3,487	22
1994	1,257	231	2,163	20
1995[a]	360	152	655	7
1996[a]	117	24	353	6
1997	766	186	512	12

[a] Unpublished results from the Alaska statewide harvest survey (A. L. Howe, Alaska Department of Fish and Game, Anchorage, personal communication); may be considered unreliable because of the small number of respondents each year.

Appendix B1.–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 C1.–Data analysis files used in the preparation of this report.

File name	Description
Sitko_96.xls	Mark-recapture, capture effort and AWL data for 1996
Sitko_97.xls	Mark-recapture, capture effort and AWL data for 1997
Sitko_98.xls	Mark-recapture, capture effort and AWL data for 1998