Fishery Data Series No. 07-32

Abundance and Length Composition of Cutthroat Trout in Patching Lake, Southeast Alaska, 2005

by

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May 2007

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_{2}, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 07–32

ABUNDANCE AND LENGTH COMPOSITION OF CUTTHROAT TROUT AT PATCHING LAKE, SOUTHEAST ALASKA, 2005

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May 2007

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-10-21, Job R-1-1.

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This document should be cited as:
Bangs, P. D. 2007. Abundance and length composition of cutthroat trout in Patching Lake, Southeast Alaska, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 07-32, Anchorage.

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ABSTRACT

A two-event mark-recapture study was conducted at Patching Lake in 2005 to estimate the abundance and length composition of cutthroat trout *Oncorhynchus clarki*. Fish were captured with hook-and-line gear and hoop traps, marked with PIT tags and given an adipose fin clip as a secondary mark. The estimated abundance of cutthroat trout ≥ 180 mm FL was 2,220 fish (SE = 224; 90% confidence interval = 1,803–2,809). Most of the cutthroat trout ≥180 mm FL in Patching Lake were estimated to be ≤299 mm FL ($\hat{p}$ = 0.95, SE = 0.01), while only a small proportion of the population ($\hat{p}$ = 0.006, SE = 0.003) was estimated to be ≥400 mm FL. Patching Lake is one of only 17 lakes in Southeast Alaska where trophy sized (i.e., ≥508 mm, or 20 in, TL) cutthroat trout have been documented. If trophy sized fish are the management objective, managers may want to consider alternative management strategies such as a maximum size limit or a slot limit in order to minimize the Darwinian consequences of size selective harvesting.

Key words: Patching Lake, Naha drainage, cutthroat trout, *Oncorhynchus clarki*, mark-recapture, length, abundance.

INTRODUCTON

The Alaska Department of Fish and Game (ADF&G) periodically conducts stock assessments of cutthroat trout *Oncorhynchus clarki* populations in Southeast Alaska (see Bangs and Harding *In press*). While most lakes in Southeast Alaska have a 279 mm TL (11 in) minimum size limit for cutthroat trout (Harding and Jones 2004), Patching Lake (near Ketchikan) is managed as a trophy lake, with a minimum size limit of 635 mm TL (25 in) and a bag limit of 1 fish. No prior studies have estimated the abundance of cutthroat trout in Patching Lake, though the presence of large cutthroat trout (i.e., ≥375 mm FL) has been documented by ADF&G (Schmidt 1977) and submittals to ADF&G's trophy fish program (i.e., ≥508 mm [20 in] TL or 1.4 kg [3 lb] minimum weight). This study was prompted by concern raised by area management biologists over anticipated proposals to the Alaska Board of Fisheries (BOF) to liberalize sport fishing regulations for Patching Lake. The goal of this assessment is to obtain an estimate of abundance and length composition to better evaluate the impact of potential BOF proposals.

OBJECTIVES

The study objectives in 2005 were to:

1. Estimate abundance of cutthroat trout ≥180 mm FL; and,
2. Estimate length composition of the cutthroat trout ≥180 mm FL.

METHODS

STUDY AREA

Patching Lake is located in the Naha River drainage on Revillagigedo Island, approximately 14 km upstream from Naha Bay (Figure 1). The Naha River is open to fish passage from saltwater upstream to a series of water falls below the outlet of Patching Lake which form a barrier to upstream movement of fish (Schmidt 1977). Patching Lake is connected to Chamberlain Lake via a narrow stretch of the Naha River. Patching Lake is narrow and steep sided, 5 km long, and covers about 207 ha. The lake has a mean depth of 30 m and a maximum depth of 67 m (Schmidt 1977). A U.S. Forest Service recreational cabin with a small skiff is located at the lake; the primary mode of transportation to the cabin is by float plane. Cutthroat trout and Dolly Varden *Salvelinus malma* are the species of fish available to anglers. In 2002, the estimated fishing effort at Patching Lake by those who reserved the U.S. Forest Service cabin was 83 days (SE = 18); the estimated catch of cutthroat trout by these anglers was 370 fish (SE = 90) and an estimated harvest of 28 (SE = 16; Harding et al. 2005).

SAMPLING DESIGN AND FISH CAPTURE

This study was designed to estimate the abundance and length composition of cutthroat trout in Patching Lake by using mark-recapture methodology. Sampling was conducted over two events in 2005; the first event (event 1) occurred from May 3 to 14 and the second event (event 2)

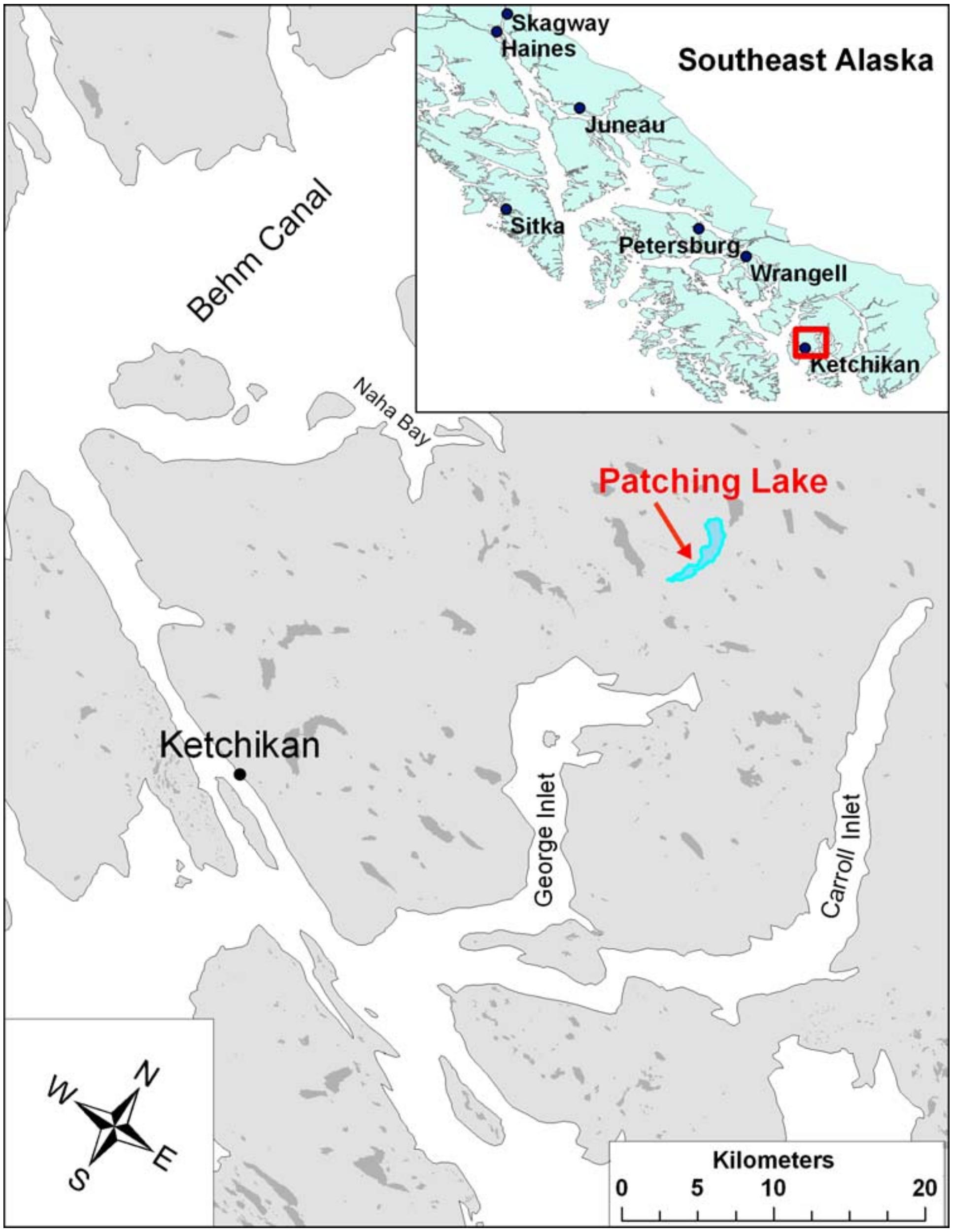

Figure 1.–Location of Patching Lake, near Ketchikan.

occurred from May 18 to 28. The rationale for the timing of these events was to avoid spawning, which presumably occurred in April, and to avoid warm water temperatures that were likely to occur later in the summer so as to reduce handling-induced stress effects on sampled fish.

Cutthroat trout were captured by employing hoop traps and hook-and-line gear. Hoop traps 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; the traps were lined with 1-cm mesh netting. Bait for the traps consisted of whole/crushed salmon eggs that had been disinfected in a povidone-iodine solution. Hook-and-line fishing was conducted by casting small spoons, spinners, and other lures in a manner such that all shoreline areas at depths ≤ 6 m were fished with similar effort. The shoreline was divided into 10 sections of equivalent length (Figure 2) to facilitate uniform hook-and-line fishing effort around the lake. A total of 40 rod-hours of hook-and-line effort were expended during each event. The lake was divided into three areas to facilitate consistent recording of capture locations and to aid in evaluation of assumptions during data analysis (Figure 2). During each sampling event (for 10 consecutive days), 12 hoop traps were set each day in a uniform manner across the lake in all areas ≤ 30 m in depth. The total sampling effort with hoop traps was 32 overnight trap sets in areas A and C and 56 overnight trap sets in area B (i.e., total of 120 overnight trap sets across all areas in each event). Traps were set on the lake bottom and depths were measured with a fathometer or metered buoy line.

All cutthroat trout ≤179 mm FL were counted and released (i.e., not sampled). This minimum size threshold for sampling was selected to be consistent with previous cutthroat trout studies in Southeast Alaska (e.g., Lum and Taylor 2004). All cutthroat trout that were ≥180 mm FL were given an adipose finclip, measured from the tip of

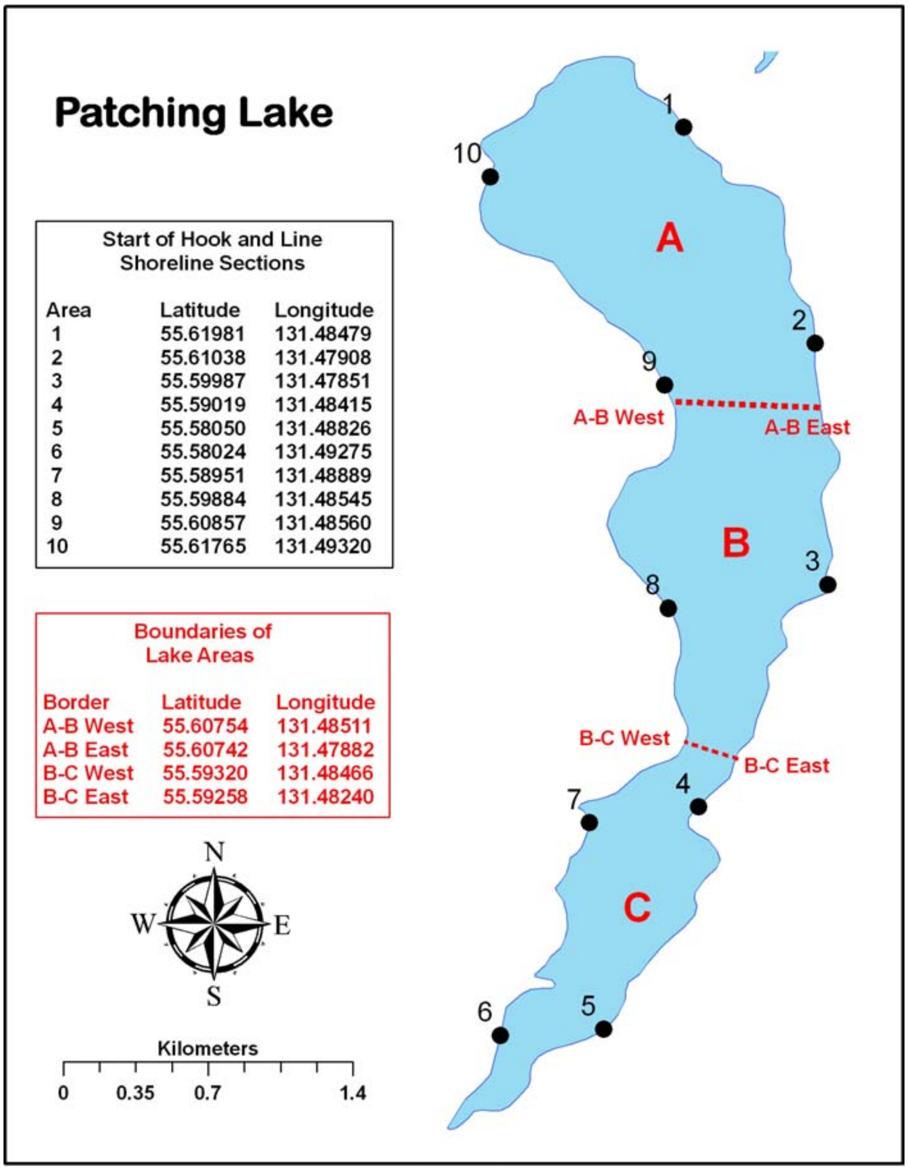

Figure 2.–Location of sampling areas in Patching Lake. The ten shoreline sections were used to ensure uniform hook-and-line fishing effort around the lake margin. The three large lake areas (A, B, C) were used to evaluate study assumptions.

the snout to the fork of the tail (to the nearest mm FL), and were given a passive integrated transponder (PIT) tag. The tag was inserted just posterior to the cleithrum into the left side of the fish, at an angle approximately 20 degrees to the mid-line. Entrance wounds caused by tag insertion were sealed with a drop of super glue. Previously captured fish (as indicated by the presence of a PIT tag or adipose finclip) were measured for length and the PIT tag number was recorded. For each fish captured, the date, time, gear type, lake area (A, B, C), and depth (for hoop traps) was recorded.

The assumptions of the experiment were that:

1) the population was closed (cutthroat trout do not enter the population, via growth or immigration, or leave the population 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 (or gain) marks between events, and marks were recognized and reported during the second event.

The closure assumption (assumption 1) relied on the relatively short time (14 days) between the two sampling events. To evaluate the possibility of handling or tagging mortality (pertinent to assumptions 1, 2, 3), the first 10 fish sampled in each event were held in a hoop trap for observation. After 4–6 hours, the status of the fish (e.g., whether they were alive, apparent condition) was ascertained to ensure that handling procedures were not detrimental.

The second assumption requires thorough mixing between marked and unmarked fish ($\geq$180 mm FL) between sampling events. This was tested with a chi square analysis comparing the numbers of marked and unmarked fish captured in each area of the lake. If the null hypothesis was rejected (α = 0.05), a stratified Peterson estimator (Darroch 1961; and Seber 1982, Chapter 11) was used. Size-selective sampling (a violation of the second assumption) was evaluated using Kolmogorov-Smirnov (K-S) tests following the protocol outlined in Appendix A1.

Mixing (assumption 2) and the effects of marking on catchability (assumption 3) were evaluated with tests of consistency for the Petersen estimator (Appendix A2). Assumption 4 should be robust in this experiment, because all fish had a secondary mark (adipose finclip) 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.

DATA ANALYSIS

The abundance of cutthroat trout was estimated in each length strata *i* by using the Chapman modification of the Petersen estimator (Seber 1982):

$$\hat{N}_i = \frac{(n_{1i}+1)(n_{2i}+1)}{(m_{2i}+1)} - 1 \qquad (1)$$

where:

$\hat{N}_i$ = the estimated abundance of cutthroat trout ≥180 mm FL in length strata *i*;

n_{1i} = number of cutthroat trout ≥180 mm FL in length strata *i* marked in event 1;

n_{2i} = number of cutthroat trout ≥180 mm FL in length strata *i* examined in event 2;

m_{2i} = number of marked cutthroat trout in length strata *i* recaptured in event 2.

The standard error and 90% confidence interval about $\hat{N}_i$ were estimated by using a parametric bootstrap routine in Excel®, whereby random variates (m_{2i}) were generated from the hypergeometric distribution based upon fixed values of n_{1i}, n_{2i}, and $\hat{N}_i$. For each of the generated m_{2i} values (5000 iterations), equation 1 was used to generate a potential abundance estimate ($\hat{N}_{k\,i,k=1-5,000}$). 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 $\hat{N}_i$ was calculated by:

$$\mathrm{var}[\hat{N}_i] = \sum_{k=1}^{B} (\hat{N}_{ki} - \overline{N}_i)^2 /(B-1) \quad (2)$$

where B indicates the bootstrap sample (5000 iterations), and $\overline{N}_i$ is the sample mean of the bootstrap estimates $\hat{N}_{ki}$. The abundance estimates for each strata i were summed to yield $\hat{N}$:

$$\hat{N}=\sum_i \hat{N}_i \quad (3)$$

A 90% confidence interval about $\hat{N}$ was calculated using the percentile approach described above. The variance of $\hat{N}$ was calculated by:

$$\mathrm{var}[\hat{N}] = \sum_{k=1}^{B} (\hat{N}_k - \overline{N})^2 /(B-1) \quad (4)$$

where $\overline{N}$ was calculated by:

$$\overline{N}=\sum_i \overline{N}_i \quad (5)$$

and $\hat{N}_k$ was calculated by:

$$\hat{N}_k = \sum_i \hat{N}_{ki} \quad (6)$$

LENGTH COMPOSITION

Size selectivity in sampling was investigated according to the protocols in Appendix A1. The estimated fraction $\hat{p}_{a,i}$ of the fish in length group a (20 mm increments) in length stratum i (e.g., large or small) was calculated as:

$$\hat{p}_{a,i} = \frac{n_{a,i}}{n_i} \quad (7)$$

where n_i is the number of large or small fish measured for length and $n_{a,i}$ is the number from this sample that belong to length group a. Note that fish from more than one length strata may occur within length group a as a result of a break between length strata occurring within length group a. The estimated variance for $\hat{p}_{a,i}$ is

$$\hat{\mathrm{var}}[\hat{p}_{a,i}] = \frac{\hat{p}_{a,i}(1-\hat{p}_{a,i})}{n_i - 1} \quad (8)$$

The abundance of length group a in the population ($\hat{N}_a$) was estimated by

$$\hat{N}_a = \sum_i \hat{p}_{a,i}\hat{N}_i \quad (9)$$

where $\hat{N}_i$ the estimated abundance in length stratum i of the mark-recapture experiment. From Goodman (1960), the variance of $\hat{N}_a$ is:

$$\hat{\mathrm{var}}[\hat{N}_a] = \sum_i \begin{bmatrix} \hat{\mathrm{var}}(\hat{p}_{a,i})\hat{N}_i^2 + \\ \hat{\mathrm{var}}(\hat{N}_i)\hat{p}_{a,i}^2 - \hat{\mathrm{var}}(\hat{p}_{a,i})\,\hat{\mathrm{var}}(\hat{N}_i) \end{bmatrix} \quad (10)$$

The estimated fraction of the population that belongs to length group a ($\hat{p}_a$) is:

$$\hat{p}_a = \frac{\hat{N}_a}{\sum_i \hat{N}_i} \quad (11)$$

The variance of $\hat{p}_a$ was approximated with the delta method (see Seber 1982):

$$\mathrm{var}(\hat{p}_a) \cong \hat{N}^{-2}\sum_i \left[\hat{N}_i^2\,\hat{\mathrm{var}}(\hat{p}_{a,i})\right] + \hat{N}^{-2}\sum_i \left[\hat{\mathrm{var}}(\hat{N}_i)(\hat{p}_{a,i} - \hat{p}_a)^2\right] \quad (12)$$

RESULTS

CATCH SUMMARY

A total of 632 unique cutthroat trout ≥180 mm were captured in this experiment; no tag loss was observed. Length measurements were either not taken or not recorded from five cutthroat trout (one in the first event and four in the second event). These fish were included in the spatial heterogeneity tests, but they were excluded from the length composition analysis, K-S tests, and abundance estimation procedures as they could not be assigned to a length stratum.

KOLMOGOROV-SMIRNOV TESTS

Stratification by length was necessary as the K-S tests indicated that there were significant differences in length composition between fish captured in the first event and fish recaptured in the second event (D = 0.20, P = 0.03, Figure 3) and between fish captured in the second event versus those recaptured in the second event (D = 0.22, P = 0.01, Figure 4).

Therefore, fish were separated into two strata to reduce heterogeneity in capture probabilities related to fish size. Stratum 1 was comprised of fish from 180 to 229 mm FL, and stratum 2 consisted of all fish ≥230 mm FL. After stratification, the K-S tests did not indicate any significant differences in length composition between fish captured in the first event and fish recaptured in the second event for stratum 1 (D = 0.14, P = 0.72, Figure 5) or stratum 2 (D = 0.15, P = 0.55, Figure 6).

Similarly, after stratification no significant differences in length composition were detected between fish captured in the second event versus those recaptured in the second event (stratum 1: D = 0.10, P = 0.95, Figure 7; stratum 2: D = 0.20, P = 0.23, Figure 8).

Because the number of recaptures in each strata was <30, an additional K-S test was conducted whereby the length composition of fish captured in the first event was compared to fish captured in the second event (see Appendix A1). No significant differences were detected in stratum 1 (D = 0.07, P = 0.61, Figure 9) or stratum 2 (D = 0.15, P = 0.13, Figure 10).

These results indicated that the data required stratification by size to estimate abundance, and length composition could be estimated using data from both sampling events (Appendix A1).

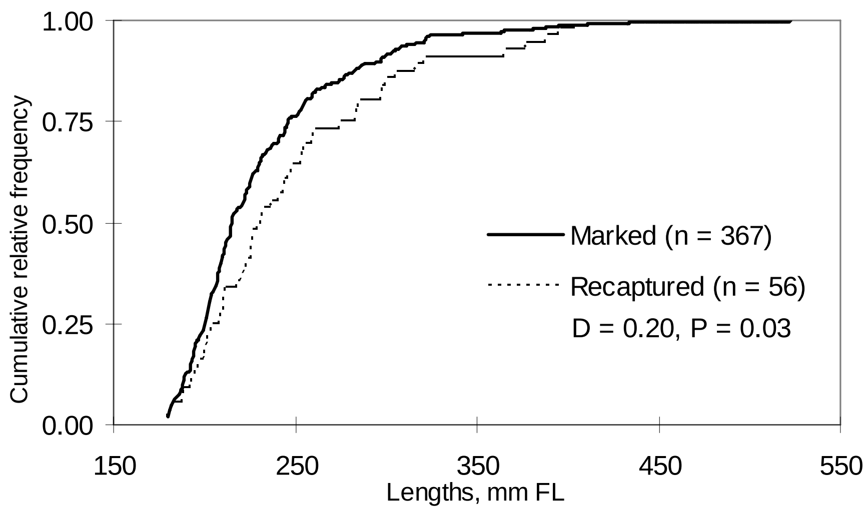

Figure 3.–Cumulative relative frequency of cutthroat trout ≥180 mm FL marked in the first event and recaptured in the second event.

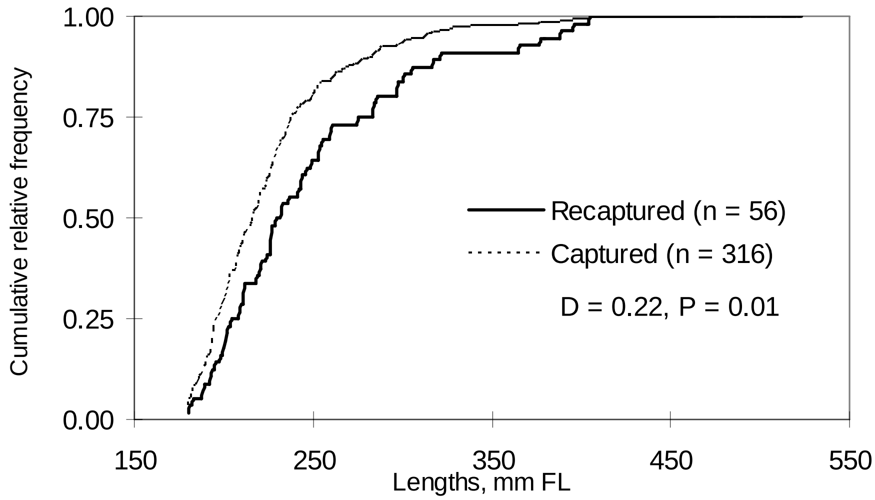

Figure 4.–Cumulative relative frequency of cutthroat trout ≥180 mm FL captured in the second event versus those recaptured in the second event.

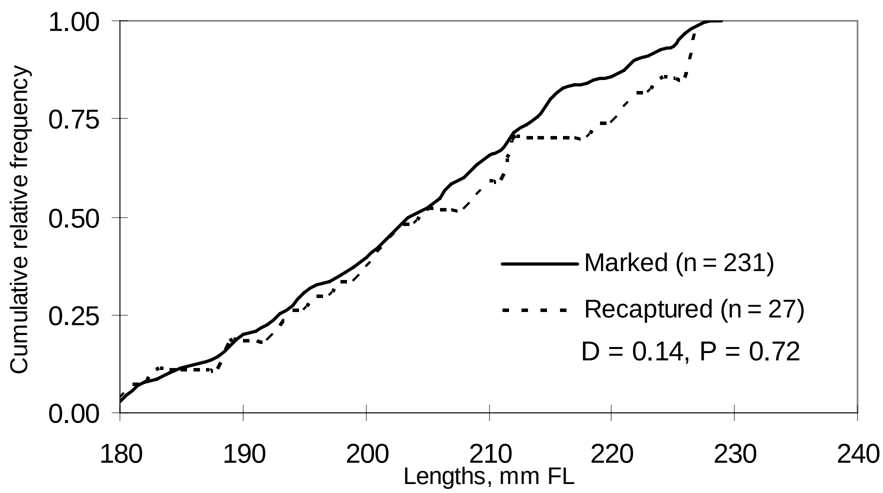

Figure 5.–Cumulative relative frequency of cutthroat trout 180–229 mm FL captured in the first event versus those recaptured in the second event.

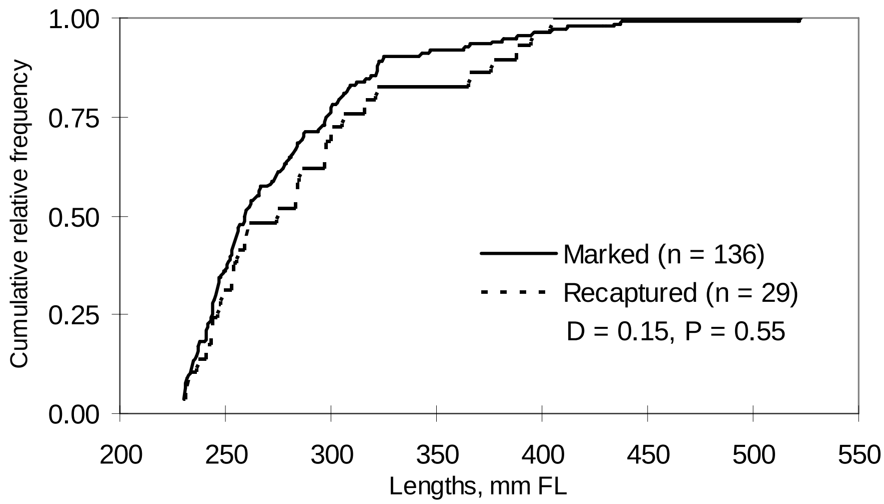

Figure 6.–Cumulative relative frequency of cutthroat trout ≥230 mm FL captured in the first event versus those recaptured in the second event.

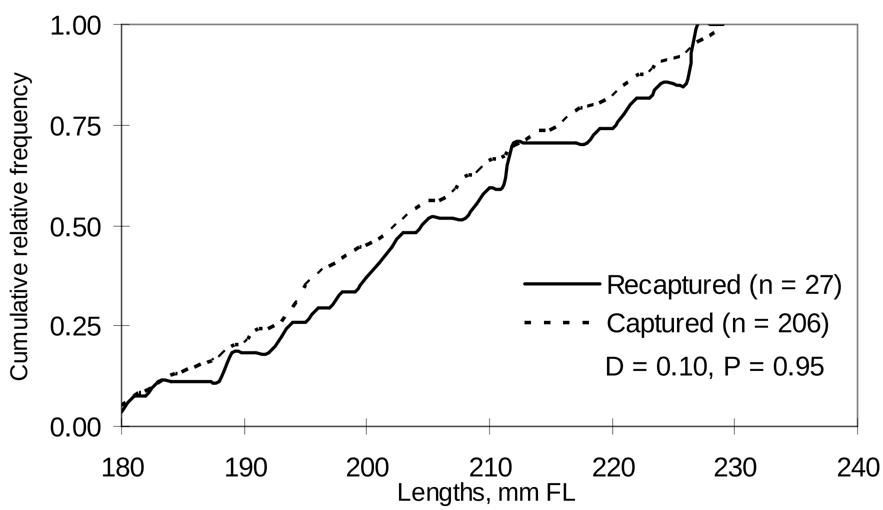

Figure 7.–Cumulative relative frequency of cutthroat trout 180–229 mm FL captured in the second event versus those recaptured in the second event.

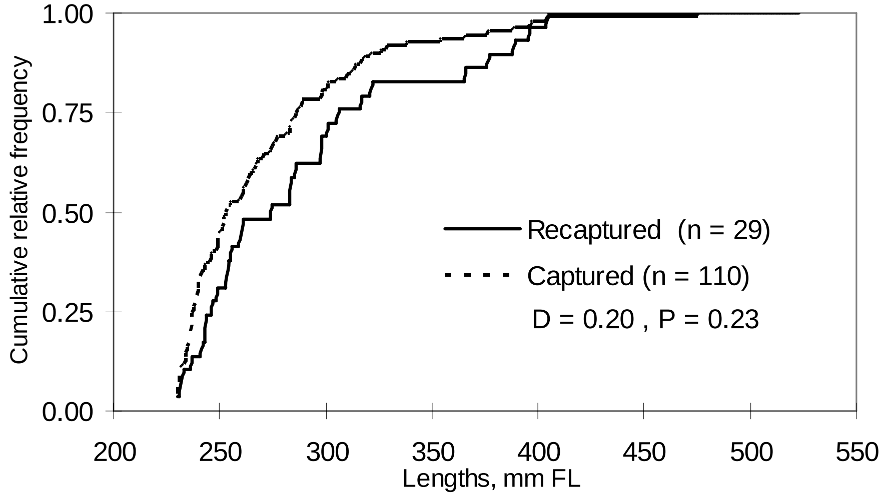

Figure 8.–Cumulative relative frequency of cutthroat trout ≥230 mm FL captured in the second event versus those recaptured in the second event.

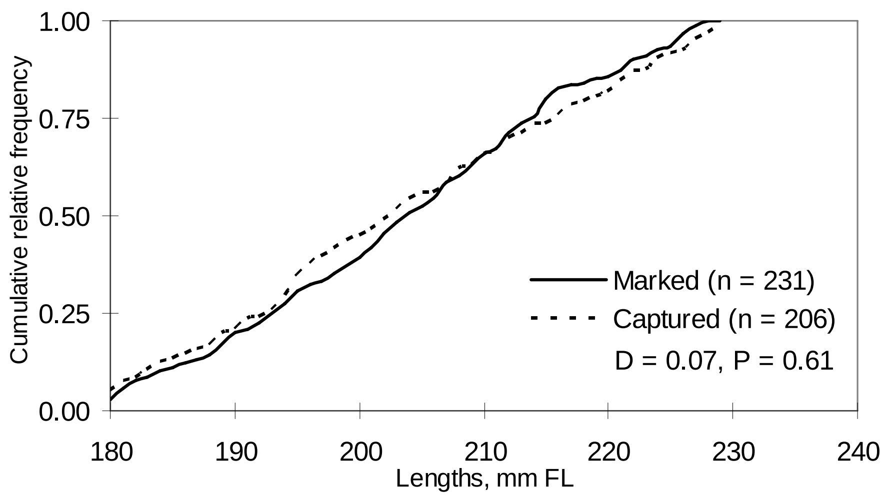

Figure 9.–Cumulative relative frequency of cutthroat trout 180–229 mm FL captured in the first event versus those captured in the second event.

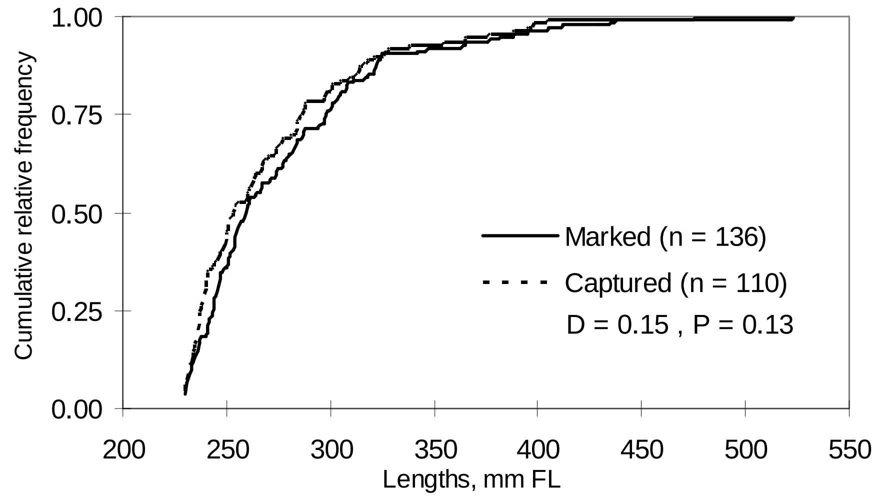

Figure 10.–Cumulative relative frequency of cutthroat trout ≥230 mm FL captured in the first event versus those captured in the second event.

SPATIAL HETEROGENEITY TESTS

Heterogeneity in capture probabilities due to spatial factors was not considered to be a significant issue in the analysis, as there was no evidence of unequal probability of capture in the first event ($\chi^2 = 2.61$, df = 2, P = 0.27, Table 1) or in the second event ($\chi^2 = 0.84$, df = 2, P = 0.66, Table 2). As the modified Petersen model only requires equal probability of capture in the first event *or* second event *or* complete mixing (i.e., only one of these conditions needs to be met), these results indicate that use of this estimator was appropriate.

Table 1.–Test for equal probability of capture during the first event for cutthroat trout ≥ 180 mm FL. Numbers of marked and unmarked cutthroat trout captured during the recapture event by area (A, B, C).

Category	Area where examined			Total
	A	B	C	
Marked (m_2)	10	27	19	56
Unmarked ($n_2 - m_2$)	74	106	84	264
Examined (n_2)	84	133	103	320
$P_{capture}$ 1st event (m_2/n_2)	0.12	0.20	0.18	0.17

$\chi^2 = 2.61$, df = 2, P = 0.27, fail to reject H_o: equal probability of capture in the first event.

Table 2.–Test for equal probability of capture during the second event for cutthroat trout ≥ 180 mm FL. Numbers of marked cutthroat trout recaptured and not recaptured from each marking area (A, B, C).

Category	Area where marked			Total
	A	B	C	
Recaptured (m_2)	15	21	20	56
Not recaptured ($n_1 - m_2$)	101	115	96	312
Marked (n_1)	116	136	116	368
$P_{capture}$ 2nd event (m_2/n_1)	0.13	0.15	0.17	0.15

$\chi^2 = 0.84$, df = 2, P-value = 0.66, fail to reject H_o: equal probability of capture in the second event.

ABUNDANCE ESTIMATE

The estimated abundance of cutthroat trout was 1,714 fish (SE = 278; 90% CI = 1,297 – 2,286; n_1 = 231, n_2 = 206, m_2 = 27) for fish 180 – 229 mm FL, and 506 (SE = 69; 90% CI = 410 – 633; n_1 = 136, n_2 = 110, m_2 = 29 for fish ≥230 mm FL. Combining these stratum estimates, the overall abundance was 2,220 (SE = 224; 90% CI = 1,803 – 2,809) cutthroat trout ≥180mm FL in Patching Lake in 2005.

LENGTH COMPOSITION

Fork lengths of measured cutthroat trout ranged from 180 to 523 mm (Table 3). Most of the

Table 3.–Length composition and estimated abundance at length for cutthroat trout ≥180 mm FL in Patching Lake in 2005. Number sampled (n_a; events 1 and 2 combined), number captured with hook and line gear ($n_{a,HL}$), proportion ($\hat{p}_a$), abundance ($\hat{N}_a$), and standard error (SE) are shown for each 20-mm length class.

Length *a*, mm FL	n_a	$n_{a,HL}$	$\hat{p}_a$	SE($\hat{p}_a$)	$\hat{N}_a$	SE($\hat{N}_a$)
180-199	176	89	0.311	0.024	690	123
200-219	187	97	0.330	0.025	733	130
220-239	131	69	0.184	0.015	407	251
240-259	69	37	0.064	0.013	142	269
260-279	36	14	0.033	0.008	74	194
280-299	30	9	0.028	0.007	62	177
300-319	22	7	0.020	0.005	45	151
320-339	11	4	0.010	0.003	23	107
340-359	3	0	0.003	0.002	6	56
360-379	5	2	0.005	0.002	10	72
380-399	6	2	0.006	0.002	12	79
400-419	3	1	0.003	0.002	6	56
420-439	2	1	0.002	0.001	4	46
≥440	2	1	0.002	0.001	4	46
Total	683[a]	333		$\hat{N}$ =	2,220	

[a] 367 (n_1) + 316 (n_2) = 683; includes 56 (m_2) recaptures.

cutthroat trout ≥180 mm FL in the population were estimated to be ≤299 mm FL ($\hat{p}_{180-299}$ = 0.95, SE = 0.01). A smaller proportion were 300 – 399 mm FL ($\hat{p}_{300-399}$ = 0.041, SE = 0.01), and very few fish were ≥400 mm FL ($\hat{p}_{400+}$ = 0.006, SE = 0.003; Table 3). Approximately 34% of the sampled cutthroat trout ≥260 mm FL were captured with hook and line gear, whereas 52% of sampled cutthroat trout <260 mm FL were captured using hook and line gear (Table 3).

DISCUSSION

ABUNDANCE ESTIMATE

Although ADF&G conducted some limited fisheries surveys in Patching Lake in 1975 (Schmidt 1977), this is the first estimate of length composition or abundance of cutthroat trout in the lake. Direct comparisons of abundance estimates from one lake to another can be misleading due to large differences in lake size or other factors, therefore comparisons of fish density (i.e., abundance of cutthroat trout divided by the surface area of the lake) may provide a more meaningful measure for comparison. Based on the abundance estimate generated via this study (2,220 fish, 90% CI = 1,803–2,809) and the surface area of the lake (207 ha), the estimated density of cutthroat trout ≥180 mm FL in Patching Lake is 10.7 fish/ha (90% CI = 8.7–13.3). This density estimate may be useful for operational planning in other lakes in Southeast Alaska where prior abundance estimates are not available, or for comparisons among lakes in futures studies.

LENGTH COMPOSITION

Most of the cutthroat trout ≥180 mm FL in the population were estimated to be ≤299 mm FL ($\hat{p}_{180-299}$ = 0.95, SE = 0.01), and a very small proportion of the population was estimated to be ≥400 mm FL ($\hat{p}_{400+}$ = 0.006, SE = 0.003; Table 3). In fact, despite our intensive sampling effort in this study (80 hours of hook-and-line effort and 240 overnight hoop trap sets), we captured only seven cutthroat trout ≥400 mm FL (only two fish were ≥440 mm FL). Caution must be taken when comparing these estimates to the samples collected by Schmidt (1977), as the sampling effort was very limited with small sample sizes (a total of 19 cutthroat trout ≥180 mm FL). Nonetheless, the contrast is striking as eight of their 19 fish sampled were ≥375 mm FL (four of which were ≥450 mm FL). Shortly after the samples were collected from Patching Lake in 1975 (i.e., Schmidt 1977), a former ADF&G biologist interviewed anglers returning from Patching Lake and observed "large coolers full of big cutthroat trout" (Mark Schwan, personal communication).

MANAGEMENT IMPLICATIONS

Patching Lake is one of only 13 lakes in Southeast Alaska managed for trophy cutthroat trout, yet very few large cutthroat trout are available for anglers to catch, let alone legally harvest (i.e., ≥635 mm, or 25 in, TL; Table 3). The situation at Turner Lake is similar (Harding et al. *In prep*), while the status of other lakes managed for trophy cutthroat trout is unknown. Although we are lacking baseline studies from 20 to 30 years ago, there is some anecdotal information (e.g., Harding et al. *In prep*) that suggests that large cutthroat trout may have been more abundant in the past. Although current regulations in Patching Lake are very restrictive, regulations were more liberal prior to 1994, with daily bag limits ranging from 10 to 15 fish in the 1970s to 5 fish in the early 1990s.

While it is impossible to determine the cause of the suspected change in length composition, recent studies have shown that size-selective harvesting can have an immediate impact on the size composition of a population (Haugen and Vollestad 2001; Conover and Munch 2002) and can also influence the size composition of future generations of fish (Conover and Munch 2002). Length- and weight-at-age are known to be heritable traits in salmonids (Gunnes and Gjedrem 1981; Gjerde and Shaeffer 1989), and recent studies by Haugen and Vollestad (2001) and Conover and Munch (2002) have provided empirical evidence that size-selective harvest of adult fish can lead to dramatic changes in life history traits such as the length-at-age, age- and length-at-maturity, spawning stock biomass, fecundity of spawning females, egg size, and larval growth rates in as few as four generations. The policy for the management of sustainable wild trout fisheries (5 AAC 75.222, adopted by the BOF in 2003) states that wild trout should be managed in a manner to maintain genetic and phenotypic characteristics of the stock. Therefore, managers should consider ways to minimize the Darwinian consequences of size-selective harvesting (Conover and Munch 2002), particularly in the populations that are known for producing trophy-sized cutthroat trout. Conover and Munch (2002) argue that maximum size limits (i.e., all fish above a given size are protected) may be preferable to minimum size restrictions, which is the current management strategy for Patching Lake. Slot limits that afford protection for large fish may also be an effective strategy. Managers should recognize that cessation of size-selective harvest does not guarantee reverse selection back to the original state (Conover and Munch 2002), or that the process could take many generations. The paucity of large cutthroat trout in Patching Lake in 2005 may be a consequence of significant harvests of large fish in the 1970s, 1980s or earlier.

ACKNOWLEDGEMENTS

The author is thankful to Ken and Karen Koolmo for their field work at Patching Lake. Amy Holm and Kurt Kondzela were very helpful with supplies and logistics. Randall Mullen provided advice for the study design and data analysis. John Der Hovanisian and an anonymous reviewer provided critical review, and Judy Shuler prepared the final manuscript for publication. Funding for this project was provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-20, Job No. R-1-1.

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APPENDIX A

Appendix A1.–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

-continued-

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.

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:

-continued-

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

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 A2.–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 event 1;

or,

Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will 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.-Test for complete mixing [a]

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

II.-Test for equal probability of capture during the first event [b]

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

III.-Test for equal probability of capture during the second event [c]

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

[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: $\theta_{ij} = \theta_j$.

[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.

[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 A3.–Computer files used to estimate the abundance and length composition of cutthroat trout ≥180 mm FL in Patching Lake in 2005.

File Name	Description
PATCH05ABUN.XLS	EXCEL spreadsheet with abundance estimates and chi-squared tests for heterogeneity in capture probabilities related to spatial heterogeneity
PATCH05KS.XLS	EXCEL spreadsheet with Kolmogorov-Smirnov size selectivity tests
PATCH05_LENGTH	EXCEL spreadsheet with length composition analysis and figures
PATCH05_DATA	EXCEL spreadsheet with Patching Lake 2005 raw data, including fish lengths, tag numbers, depths, gear type, and comments