Fishery Data Series No. 09-69

Abundance, Length, Age, Mortality, and Maximum Sustained Yield of Cutthroat Trout at Turner and Baranof Lakes, Southeast Alaska, 1994 through 2003

by

Roger D. Harding,

Robert P. Marshall,

and

Peter D. Bangs

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 09–69

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by
Roger D. Harding
Division of Sport Fish, Douglas

Robert P. Marshall
RTS, Division of Sport Fish, Douglas

and
Peter D. Bangs
Division of Commercial Fisheries, Douglas

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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Roger D. Harding[a]
Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

Robert P. Marshall
Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

and
Peter D. Bangs
Alaska Department of Fish and Game, Division of Commercial Fisheries
P.O. Box 115526, Juneau, AK 99811, USA

[a] *Author to whom all correspondence should be addressed: roger.harding@alaska.gov*

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ABSTRACT

The abundance and survival of cutthroat trout *Oncorhynchus clarkii* were estimated annually at Turner and Baranof lakes between 1994 and 2003 using a combination of closed-population (CP) and open-population Jolly-Seber (JS) abundance models. Abundance at Turner Lake using CP model estimates averaged 2,047 (SD = 560) and ranged from 1,609 (SE = 420) to 3,575 (SE = 785). There was no trend in these estimates over time. Annual survival at Turner Lake averaged 0.63 (SD = 0.13) and maximum sustain yield (*MSY*) based on estimated carrying capacity (average abundance), survival, and a value for the intrinsic rate of population increase (a) of 0.3 is 248 fish ≥180 mm FL (12% of average abundance).

Abundance at Baranof Lake using CP model estimates averaged 8,235 (SD = 1,980) fish ≥180 mm FL and ranged from 5,616 (SE = 573) to 12,511 (SE = 1,059). There was no trend in these estimates over time. Annual survival at Baranof Lake averaged 0.52 (SD = 0.12) and *MSY* based on estimated carrying capacity, survival, and a value of $a = 0.3$ is 1,575 fish ≥180 mm FL (19% of average abundance).

Fish ages based on scale patterns were estimated and compared to ages based on tagging studies. Significant imprecision and bias in the estimated ages, increasing rapidly with fish age, were discovered.

Key words: Cutthroat trout, mark–recapture, abundance, survival, aging, *MSY*, Turner Lake, Baranof Lake, Petersen model, Jolly-Seber model, Southeast Alaska, surplus production.

INTRODUCTION

Southeast Alaska contains hundreds of lakes, rivers, and streams that foster small to large populations of cutthroat trout *Oncorhynchus clarkii*. A trend of declining trout harvests in Southeast Alaska (SE AK) in the 1980s prompted a general conservation concern and studies to investigate specific populations (e.g., Jones et al. 1992; Schmidt 1994; Hoffman and Marshall 1994; DerHovanisian and Marshall 1995; Harding 1995; Yanusz and Schmidt 1996; Freeman et al. 1998; Schmidt et al. 1998; Jones and Harding 1998; Brookover et al. 1999).

More conservative harvest regulations affecting all trout fisheries in SE AK were adopted by the Alaska Board of Fisheries (BOF) in 1994, and research to evaluate management strategies for cutthroat trout in the region began at Turner and Baranof lakes (Figure 1). The first objective of the research was to establish effective experimental procedures for estimating abundance in these large, deep non-anadromous lakes. The long-term goal of the project was to estimate maximum sustained yields (*MSY*) at these locations through annual monitoring of the abundance, size, and age of the populations. These non-anadromous populations were selected for their relatively high (Baranof) and low (Turner) densities (productions) of cutthroat trout, with the idea that the contrast between *MSY* estimates for these lakes would help us bracket reasonable harvest rates for other non-anadromous lake populations in SE AK.

This report presents stock assessment data for cutthroat trout ≥180 mm FL based on mark–recapture (m-r) studies conducted between 1994 and 2003. Results include estimates of abundance, survival and birth rates, length composition, age based on reading scales, estimates of *MSY* based on our estimates of natural mortality, and the estimated carrying capacities of these lakes. We illustrate the challenges and difficulties encountered in these stock assessments and offer recommendations for future studies.

Study Sites

Turner Lake (Figure 2) is located in upper Taku Inlet, 26 km east of Juneau. The lake is 14 km long, has a surface elevation just over 22 m, and a surface area of approximately 1,270 ha. The lake is very steep-sided except near the inlet streams and has a maximum depth of 215 m (Schmidt 1979). The lake outlet flows about 1,700 m to the Taku Inlet and is blocked to upstream fish passage by a barrier falls just below the lake. Turner Lake was once known for its production of "trophy" sized (≥20 inch, about 3 lb.) cutthroat trout. The largest trophy fish reported weighed 6 lb 7 oz (Jones and Harding 1991). In 1991 the harvest of cutthroat trout was prohibited by emergency order due to the long decline in harvest, continued angling pressure, and high exploitation rates that

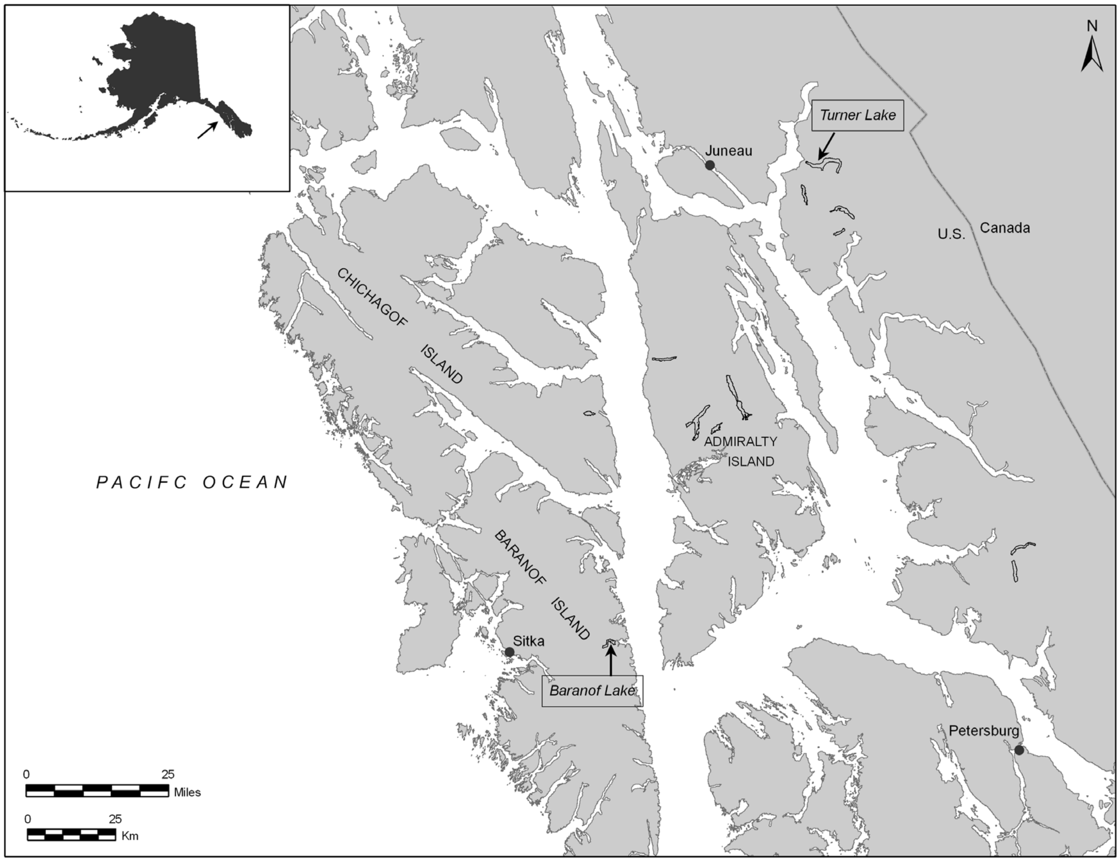

Figure 1.–Location of Turner and Baranof Lakes in Southeast Alaska.

were estimated for the system (Jones and Harding 1991). Early quantitative studies estimated the abundance of cutthroat trout in Turner Lake at 1,753 for all fish ≥40 mm FL (1,148 for fish >200 mm FL) during 1988 (Jones et al. 1989), 1,526 during 1989 (for all sizes <400 mm FL, Jones et al. 1990), and 1,242 during 1990 for fish 161–280 mm FL (Jones and Harding 1991).

Baranof Lake (Figure 3) is located 25 km east of Sitka at the head of Warm Springs Bay on Baranof Island. The lake is about 4.8 km long and 0.6 km wide, and has a surface area of 324 ha, a maximum depth of 87 m, and mean depth of 38 m (Schmidt 1982). A barrier falls on the lake outlet prevents upstream fish migrations. Baranof Lake is relatively unique among large lakes in Southeast Alaska in that it supports only 1 species of fish (cutthroat trout). A natural hot springs adjacent to the lake also makes this a popular recreation site. The abundance of cutthroat trout ≥180 mm FL in Baranof Lake in 1994 was estimated at 12,186 (DerHovanisian and Marshall 1995).

METHODS

CAPTURE, TAGGING AND RECOVERY

Cutthroat trout ≥180 mm FL were captured, marked with uniquely numbered tags, and released into Turner and Baranof lakes several times each year from 1994 through 2003 (Table 1). Capture histories were summarized for annual, 2-event closed-population (CP) m-r models, and for trip-by-trip and annual open-population (Jolly-Seber, or JS) m-r models to estimate the abundance of fish ≥180 mm FL (Seber 1982; Pollock et al. 1990).

Two to four 10-day sampling trips were made annually to each lake, beginning in early spring. Dates to begin sampling each lake were generally set to meet logistical needs. Repeated trips within years were typically separated by 5–10 days,

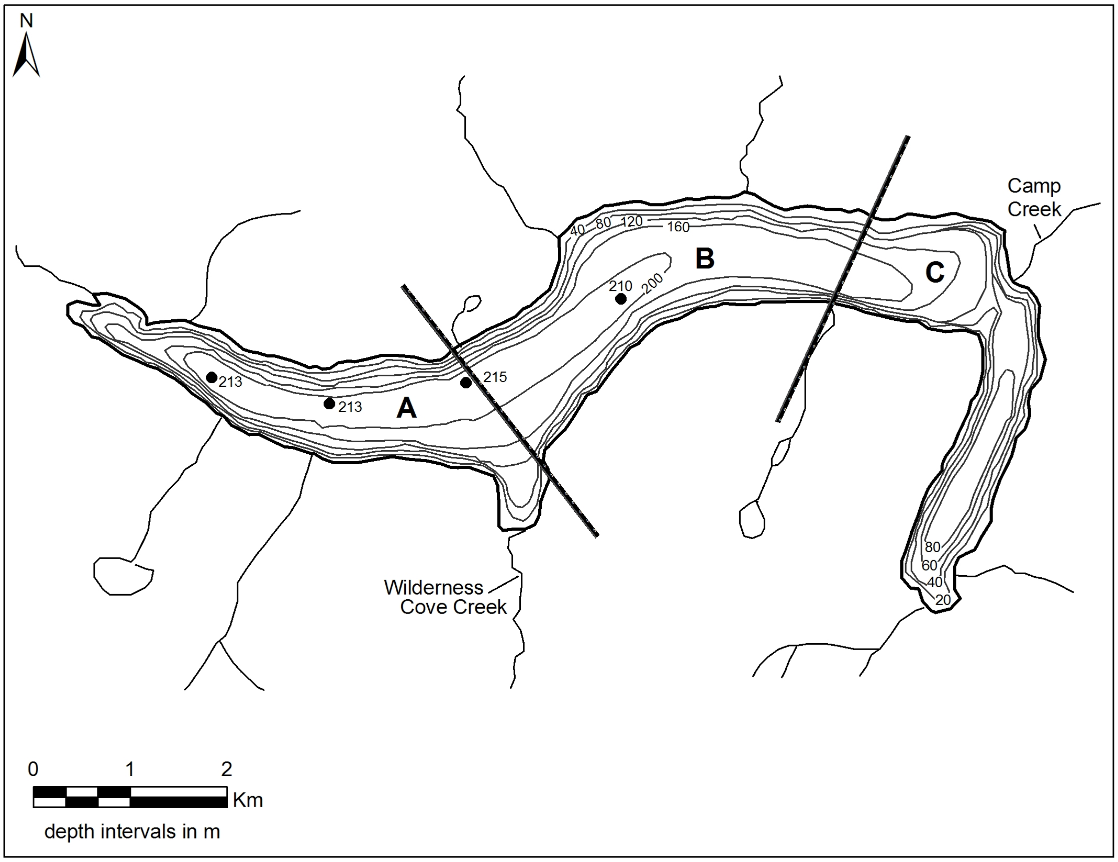

Figure 2.–Bathymetric map of Turner Lake with study area divisions.

although a few longer breaks (3–11 weeks) were scheduled to add summer sampling periods (Table 1). Tagging data from the 1994 study (Table 1, DerHovanisian and Marshall 1995) are used in this study to increase the length of the Jolly-Seber experiment to estimate population statistics at Baranof Lake.

During each sampling trip, large (about 1-m long), minnow-type traps ("large traps" or LT, Figure 2 in Rosenkranz et al. 1999) baited with salmon eggs were systematically moved around the lakes to achieve uniform coverage at depths ≤50 m in Baranof Lake and ≤30 m in Turner Lake. Traps were set overnight (a typical soak time was 22 hours) and depths were measured with a fathometer. Hook-and-line (HL) sampling around the lake perimeters was also conducted by spin-casting lures from a boat. In addition, hoop nets were deployed at both lakes in 1994 and Turner Lake in 2002; troll gear was employed in offshore areas at both lakes in 1996.

Captured cutthroat trout ≥180 mm FL were examined for marks, measured to the nearest mm FL, tagged (if unmarked), given secondary marks to permit estimation of tag loss, and released in the area where captured. Captured cutthroat trout <180 mm FL, Dolly Varden *Salvelinus malma*, and kokanee *O. nerka* were counted and released.

Sampling techniques evolved over the 10-year study period, especially at Turner Lake. Anchor T-bar tags were used to tag fish at Turner Lake until 1997, and then passive integrated transponder (PIT) tags replaced them. Alpha-numeric visual implant (VI) tags were also used as a secondary mark at Turner Lake before 1999 (Appendix A1). In many cases the numbered VI tags permitted us to maintain a capture history of a fish that lost its anchor T-bar or PIT tag. Anchor T-bar tags were used throughout the experiment at Baranof Lake (Appendix A2). Dye-marks were applied at both lakes (from 1998 at Baranof Lake and 1999 at Turner Lake) to evaluate if this

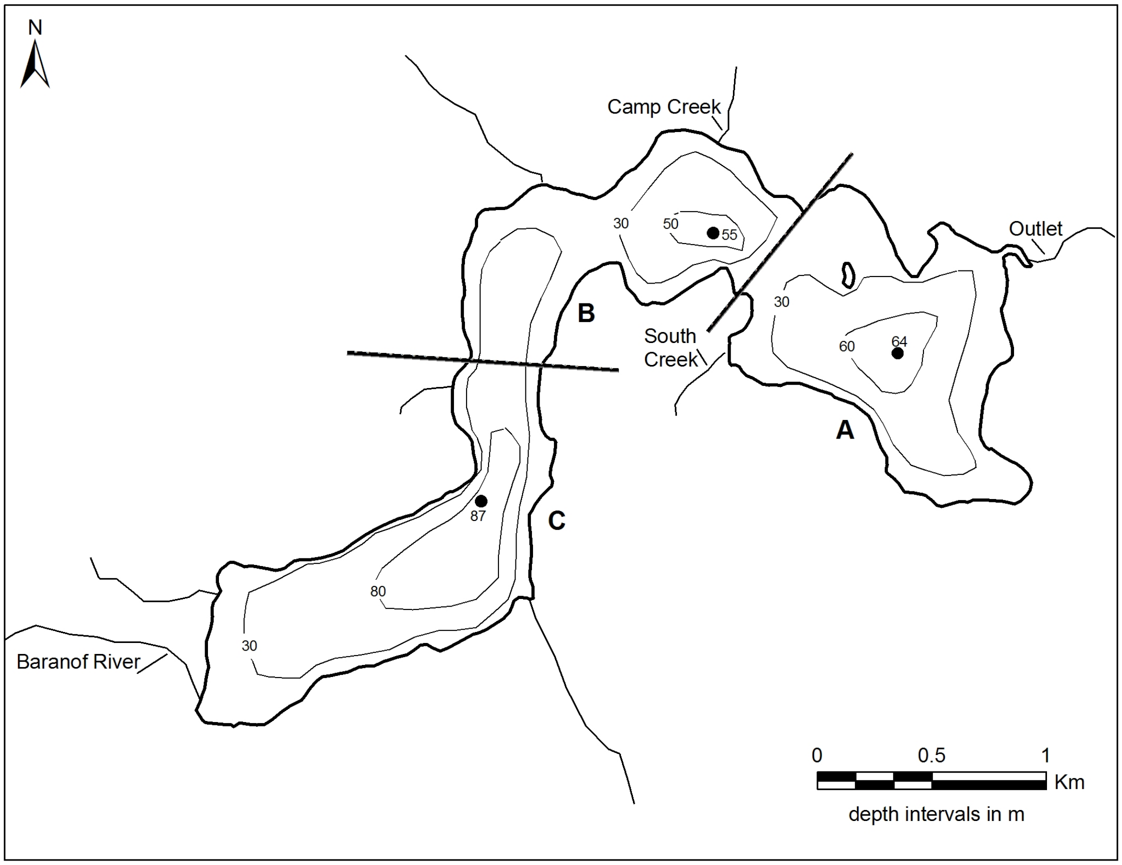

Figure 3.–Bathymetric map of Baranof Lake with study area divisions.

Table 1.–Dates of sampling trips at Turner and Baranof Lake, 1994 to 2003.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
					Turner Lake[a]					
Trip 1	13-Jul	26-Jul	31-May[b]	25-Jul	9-Jul	13-Jul	15-Jun	19-Jun	20-Jun	18-Jun
Trip 2	27-Jul	8-Aug	12-Jun[b]	6-Aug	24-Jul	28-Jul	28-Jun	5-Jul	8-Jul	5-Jul
Trip 3	16-Aug[b]		9-Jul							
Trip 4	31-Aug[b]									
					Baranof Lake[a]					
Trip 1	10-May	10-May	7-May	14-May	29-Apr	5-Jun	10-May	8-May	25-Jul	6-May
Trip 2	25-May	25-May	20-May	23-May	19-May	25-Jun	31-May	5-Jun		21-Jul[b]
Trip 3	7-Jun[b,c]	23-Aug[b]					15-Jul[b]	21-Jul[b]		
Trip 4		5-Sep[b]								

[a] First day of each 9-day sampling trip.

[b] Data not used to construct length composition estimates.

[c] Fish not marked with numbered tags (DerHovanisian and Marshall 1995).

technique was a suitable replacements for finclips. Secondary marks (various finclips) were used at both lakes to control for tag loss.

Anchor T-bar tags were inserted on the left side of the fish immediately below the dorsal fin. VI tags were inserted in clear tissue just posterior to the left eye. PIT tags were first inserted slightly ventral to the dorsal fin but the location was subsequently changed to just posterior to the cleithrum into the left side of the fish, at about a 20-degree angle to the mid-line; all entrance wounds caused by PIT tag insertion were washed with an antiseptic solution and sealed with a drop of cyanoacrylate adhesive (i.e., Super Glue[1]).

Tag loss was estimated annually in each lake by dividing the total number of sampled fish that appeared to have lost a primary tag (based on secondary marks) by the total number of fish recaptured (including those with lost tags). Tag loss estimates at Tuner Lake were generated for each type of tag (i.e., anchor T-bar and PIT). Because numbered VI tags were used as secondary marks at Turner Lake before 1999, it was often possible to maintain the tagging history of a fish recaptured without its primary tag. Thus, effective rate of tag loss (the rate germane to the m-r experiment) was also tallied for the Turner Lake experiment. Estimates of tag loss at Baranof Lake for the period 1995–1998 were reported as a range of estimates because during some sampling days of the third trip in 1994, fish were given an adipose finclip but no anchor T-bar tag.

Catch per unit effort (CPUE) by gear type was estimated for each sampling trip. Trends in CPUE were clearly evident as function of sampling date. Because independent m-r estimates of abundance were available for each trip, CPUE was normalized by abundance to yield catchability (Q = CPUE/ N), which was plotted against sampling date to illustrate the trends over time.

WATER TEMPERATURES

Recording thermometers were installed in selected inlet streams and in each lake in 1999, and maintained annually. These streams (Baranof River or "Main Inlet," and Camp and South creeks at Baranof Lake, and Camp and Wilderness Cove creeks at Turner Lake, Figures 2 and 3) were accessible, small streams where cutthroat trout were known to spawn. Temperatures were measured mid-depth near the middle of the stream every 2 hours.

Lake temperature and conductivity profiles, measured at the center of each lake at depths between the surface and 50 m, were also taken each trip.

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

Compiled temperature records were compared to our m-r sampling dates to help determine if, based on a reported temperature-spawning relationship (Behnke 1992), cutthroat trout may have been spawning when we sampled. According to Behnke (1992), "temperatures of about 3 to 6°C may initiate spawning activity and actual spawning typically occurs when daily maximum water temperatures reach 6–9°C."

MARK–RECAPTURE-CP MODEL

Lincoln-Petersen models were constructed using 2 consecutive sampling trips each year, at as similar annual dates as possible. We did not pool data for the CP analysis across excessively dispersed sampling trips or times of the year, and fish captured more than 1 time during a sampling period were considered as "redundant" and treated as being caught only once. Assumptions required for accurate statistics with the single mark release CP model are:

1) recruitment (due to growth or immigration) and death (or emigration) do not occur between sampling events;
2) every fish has an equal probability of being captured during the first or second sampling event, or marked and unmarked fish mix completely between sample events;
3) handling and marking do not affect probability of capture in the second event;
4) marked fish are neither lost or overlooked.

We did not test the first (closure) assumption directly, although survival and birth (recruitment) statistics from our trip-by-trip JS analysis provided estimates germane to evaluating this assumption. Also, the relatively short time that spanned most inter-annual samplings (Table 1) worked to minimize the possibility of significant entries into or departures from the population. The possibility of size-selective sampling (a violation of the second assumption) was investigated using a 2-sample Kolmogorov-Smirnov (KS) test (Conover 1980) comparing the distribution of fish lengths marked in the first sampling trip to the distribution of lengths for fish recaptured in the second sample. Rejection of the hypothesis of equal length distributions suggested stratifying the m-r data by length prior to estimating abundance.

Two chi-square tests (Seber 1982:438-39; Arnason et al. 1996) were used to evaluate the second assumption from spatial and mixing perspectives. The tests estimate probabilities that 1) fish marked in the different areas were recaptured at equal rates in the second sample, and 2) marked fractions were similar in each recovery area. Each lake was divided into 3 areas of roughly similar size to facilitate the tests (Figures 2 and 3). Use of the Petersen model was supported if either of the tests yielded a non-significant result; otherwise a spatially stratified model was suggested. Darroch-Plante estimators implemented in the computer program SPAS (Arnason et al. 1996) were used to estimate abundance with spatially stratified models.

We relied on experienced technicians and procedures to minimize stress on captured fish and avoid negative impacts due to handling and tagging (assumption 3). Significant (short-term) mortalities related to handling and tagging would however be indicated by a chi-square test (made as part of the JS analysis) that is described below. Assumption 4 was robust in this experiment because all sampled fish were given or inspected for secondary marks.

Mark–Recapture-JS Models

"Full" JS models were fit to our data, yielding k-2 abundance (N), k-2 survival rate (ϕ), and k-3 birth/recruitment (B) estimates (k = number of the sampling trips). Besides a "trip-by-trip" JS model, we pooled data by year to yield an 8-event "annual" JS model for each lake. In making each model, fish captured more than once during a sampling period were treated as being captured but once.

Assumptions required for accurate statistics with the Jolly-Seber model are:

1) all fish in the population at the time of ith sample have the same probability of capture;
2) all marked fish in the population immediately after the ith sample have the same probability of surviving until the (i+1)th sample;
3) fish do not temporarily leave the population (or become uncatchable) then return at later time;
4) marks are not lost or overlooked;
5) sampling is instantaneous.

Two goodness-of-fit (GOF) tests were used to test for homogeneous capture and survival probabilities (assumptions 1 and 2). The tests (Pollock et al. 1985, p.23) compare different groups of fish according to their mark status (i.e., newly marked and previously marked) using program JOLLY (Brownie et al. 1986). Both tests have similar abilities to detect heterogeneous capture probabilities while the second test is better at detecting heterogeneous survival probabilities (Pollock et al. 1990, p.24). The first test is also good at detecting *short-term* (one-period) mortality related to tagging and handling. The sum of chi-squares from both tests forms an omnibus test for violations of the equal probability of capture and survival assumptions of the JS model. If the GOF tests indicated the full JS model did not fit the data ($\alpha < 0.1$), a generalized JS model that compensates for the heterogeneity among marked groups was fit to the data.

The overall GOF test noted above likely has some power to detect temporary emigration (assumption 3; Pollock et al. 1990, p.26). As noted earlier, assumption 4 appears robust in this experiment. Pooling data by year to make the annual JS model presumes minimal death and recruitment between trips. Departures from assumption (5), with respect to the annual JS model, will be indicated by significant recruitment or deaths between trips within a year, as seen in the trip-by-trip results.

The software program POPAN (Arnason et al. 1998) was used to obtain capture histories and estimate population parameters. Estimates from the full JS model were constrained to admissible values ($\phi \leq 1$ and $B > 0$) using the procedures in Schwarz et al. (1993) and Schwarz and Arnason (1996) as required. Estimates under the generalized JS model (POPAN model "3") were obtained using a modified estimate of the number of marked fish in the population (Arnason et al. 1998), rather than estimating separate survival rates for the 2 groups of marked fish (as in

JOLLY) because this later method precludes estimating abundance.

Abundance and Survival

A "robust" modeling approach recommended by Pollock et al. (1990) was adapted for estimating abundance and survival at each lake. Estimates of abundance in a year were from the CP modeling described above, and year-to-year survival estimates came from the annual JS model just described. As described by Pollock et al. (1990, p.56), "this modeling approach allows population size estimation under [CP] models allowing unequal catchability while survival estimation, which is not so affected by unequal catchability, is under the Jolly-Seber model."

We cannot model heterogeneity in capture probabilities (using a program like CAPTURE) as envisioned by Pollock et al. because we made only 2 sampling trips to each lake in most years. We can however refer to results from the trip-by-trip JS models that are germane to closure and adequacy of a CP model. In particular, evidence from the JS model of recruitment (e.g., births) and/or mortality between the 2 spring/summer sampling trips dictate whether CP estimates would be germane to both sampling (temporal) periods, only the first (mortality is evident) or second (births are evident), or neither (both births and recruitment are evident). Similarly, a finding of significant heterogeneity in trip-by-trip JS model data suggests estimates from Petersen models could also suffer some effects from the heterogeneity exposed in the longer data analysis.

Age, Length, and Abundance-at-Length

The length composition of cutthroat trout ≥180 mm FL in each lake was estimated for each year. Age composition of fish ≥180 mm FL was estimated for a selection of the sampled years: 1995–2001 at Turner Lake and 1994, 1998, and 2003 at Baranof Lake. Standard sample summary statistics were used to calculate the estimated proportions (Cochran 1977).

Length and scales were collected from every fish ≥180 mm FL captured at Turner and Baranof lakes with the exception that only every-other newly captured fish at Baranof Lake during 2001 and 2002 and every third fish captured at Baranof Lake in 2003 was sampled for scales. Age compositions at Turner Lake were estimated from scales of all fish sampled, or from a sample of 300 randomly selected scales if more than 300 scale samples were collected in a year. Aging the scales proved very time consuming and problematic and scales collected at Turner Lake in 1994, 2002, and 2003 were thus not aged due to budgetary and time constraints. Scales collected at Baranof Lake were generally more difficult to read than those from Turner Lake. Therefore, only 150 randomly selected scales sampled in May of 1994, 1998, and 2003 at Baranof Lake were aged.

The length composition of the population sampled at each lake and each year was estimated using the lengths of uniquely numbered fish sampled in each trip. The length samples were pooled across trips to yield, as possible, temporally-comparable estimates of length composition during late-June and July in Turner Lake and mid-May and early-June in Baranof Lake. Lengths sampled during the first 2 trips to each lake in each year were typically those used to estimate annual length composition (Table 1). The number of cutthroat trout in 20 mm length intervals was estimated as the product of the proportions-at-length and the abundance estimate for each year; a variance for the product of independent variables was estimated using the procedure in Goodman (1960).

Fish age was estimated by counting annuli on the sampled scales. Recommendations in Ericksen (1999) for collecting, preparing, and aging scales were observed. Each scale was viewed ("read") independently on at least 2 occasions by a single reader. If the first 2 readings disagreed, the scale was read a third time, again without knowledge of the previous estimates. When 2 of 3 readings agreed, the similar values were adopted; if all 3 readings disagreed, age was estimated as the average, rounded to the nearest integer value. The scale reader also read a collection of 318 scales from fish tagged and later recaptured at Turner Lake since 1994. Ages estimated from reading these scales were compared to estimates of "true age" defined as the interval between tagging and recovery plus the estimate of age at the first tagging. This comparison was made to model potential bias in the age estimates using the methods detailed in Ericksen (1997).

A smear of scales was collected from the left side of the caudal peduncle of each newly-captured fish (Brown and Bailey 1949, 1952; Laakso and Cope 1956). Scales from recaptured fish were taken on the right side of the caudal peduncle. Beginning in 1999, scales from previously recaptured fish (distinguished by 2 or more annual batch marks) were sampled slightly anterior to the "normal" area on the fish's right side (to better avoid collecting regenerated scales)

MAXIMUM SUSTAINED YIELD

A simple method for approximating the *MSY* that can be supported by a population is

$$MSY = a\,M\,K$$

where a = a constant, M = instantaneous rate of natural mortality, and K = the carrying capacity of the environment (Ricker 1975; Gulland 1983). A conservative value for a of 0.3 is thought to be appropriate for many stocks (Gulland 1983). This formulation is useful when an age-based assessment of surviving recruitment across several brood years is unavailable, as in this study (see "Results"). Parameter M is related to the instantaneous rate of (overall) mortality Z and the instantaneous rate of fishing mortality F, as Z = M + F. Because $Z = -\ln(S)$, where S = an annual survival rate, we have the relation

$$MSY = 0.3(-\ln(S) - F)\ K$$

where *F* can be estimated

$$F = \frac{Z}{A} \cdot \frac{H}{N}$$

and *A* = 1 – exp(-*Z*) is the annual mortality rate, *H* = harvest, and *N* = abundance. All of these quantities are of course estimates, but for simplicity we have not scripted symbols with hats (^).

We applied this model by noting that in the absence of harvest, a very good estimate of the carrying capacity K is simply the average of several good estimates of N (i.e., $K = \overline{N}$), especially if in a time series, the Nt appear stationary (appear to have a constant mean) over time. A series of good estimates of S might lead to a good estimate of M as described above. In these situations, very precise values of M $(= \overline{M})$ and K $(= \overline{N})$ could be estimated from a long (e.g., 8–10 year) series of estimates. In this situation, an estimate of the variance for MSY could be calculated with little uncertainty, treating the parameter a as a constant. However, such a variance estimate could be very misleading because we see no way to access uncertainty (or bias) in our assignment of a (= 0.3 as noted above). We thus view our estimated values of MSY as precise approximations with an unknown accuracy or bias; further discussion of these estimates is provided below.

RESULTS

TURNER LAKE

Capture, Tagging and Recovery

A total of 5,744 cutthroat trout between 180 and 605 mm FL were captured in Turner Lake between 1994 and 2003. Most were caught using HL (58%) and LT (37%, Table 2). An additional 1,370 cutthroat trout <180 mm FL and 10,919 Dolly Varden were also captured (Appendix A3). Catches were made by fishing an average of 6 to 25 (average 15) LT and 1.3 to 8.6 (average 5.0) rod-hours per day during each 10-day sampling trip. CPUE and catchability for LT increased in late-May then declined slowly, while CPUE and catchability for HL increased steadily from late-May until early-July (Figure 4, Appendix A4).

Overall physical tag loss ranged from 0.5% to 17%, whereas effective tag loss (the fraction of recoveries not marked by either a uniquely numbered primary or secondary tag) ranged from 0.4 to 6.5% (Table 3). Annual variation in the rate of physical loss of anchor T-bar tags (up to 28%) was high, and tag loss would have been problematic if uniquely numbered secondary tags had not been employed. We have no explanation for the high rates of anchor T-bar tag loss (23–28%) seen at Turner Lake in 1997–1998. The rate of PIT-tag loss observed annually was low (average = 3%, maximum rate of loss = 6.3%).

Table 2.–Catch of cutthroat trout ≥180 mm FL by gear type and trip at Turner Lake.

Year	Trip	Period	Large trap	Hoop net	Hook & line	Troll	Total Trip	Total Year
1994	1	1	154	52	91		297	1,143
	2	2	159	42	106		307	
	3	3	107	47	128		282	
	4	4	76	38	143		257	
1995	1	5	70		209		279	480
	2	6	54		147		201	
1996	1	7	102		4	1	107	376
	2	8	55		28	22	105	
	3	9	60		98	6	164	
1997	1	10	93		378		471	849
	2	11	89		289		378	
1998	1	12	79		147		226	395
	2	13	62		107		169	
1999	1	14	78		89		167	332
	2	15	43		122		165	
2000	1	16	103		122		225	511
	2	17	97		189		286	
2001	1	18	104		131		235	510
	2	19	57		218		275	
2002	1	20	66	98	93		257	470
	2	21	52	12	149		213	
2003	1	22	159		178		337	678
	2	23	178		163		341	
Total			2,097	289	3,329	29	5,744	5,744

Table 3.–Tag loss at Turner Lake, 1994–2003.

	Tag loss rate (%)					
	Physical loss[a]			Effective loss[b]		
Year	Over-All	T-Bar	PIT	Over-All	T-Bar	PIT
1994	4.6	4.6	-	3.1	3.1	-
1995	11.0	11.0	-	6.5	6.5	-
1996	4.1	4.1	-	4.1	4.1	-
1997	17.0	23.0	2.6	0.4	0.5	0.0
1998	15.0	28.0	4.2	1.6	3.8	0.0
1999	3.6	3.6	3.5	1.2	3.6	0.0
2000	3.8	11.0	1.6	1.9	2.9	1.6
2001	6.1	0.0	6.3	4.8	0.0	5.0
2002	1.1	9.1	0.6	1.1	9.1	0.6
2003	0.5	0.0	0.5	0.5	0.0	0.5

[a] All cases a primary tag appeared to have been lost.

[b] Subset of fish with no primary tag *and* no VI tag.

Water Temperatures

Water temperatures in monitored spawning streams at Turner Lake typically reached the 6°C to 9°C temperature range that Behnke (1992) reports for spawning, well before our fish sampling surveys occurred (Figure 5). Our efforts to avoid sampling during spawning periods were thus likely successful at Turner Lake.

Mark–Recapture-CP Model

Size-selective sampling was not apparent (Appendix B1). Small sample sizes (10–20 recaptures) help lead to a visual (rather than statistical) perception that sampling gear selected against smaller size fish in some years (1996, 1998, 1999, and 2001). However, statistically, size selectivity was suggested in only 2 of 10 years (Table 4; 1995, P = 0.02; 1998, P = 0.05) and thus we concluded that adjusting for possible size selectivity was unwarranted in this analysis.

The Petersen CP model of abundance for each sampling year was suggested (over stratified or Darroch models) by the chi-square tests used to evaluate the equal probability of capture assumption. In eight of the 10 years, fish marked in the different areas were either recaptured at equal rates, or marked fractions were similar in each recovery area (Table 4). Estimates of abundance were fairly steady (average 2,047) except in 2001 when the estimate was 3,575 (SE = 785). Excluding 2001, the CP abundance estimates averaged 1,877 and ranged from 1,609 to 2,207.

Mark–Recapture-JS Models

Summary statistics for the 22-trip JS model (Table 5) show that good sample sizes were obtained in each sampling period (an average of 13% of the estimated population, with a range of 4% to 26%). Preliminary analysis showed that data from the last sampling trip at Turner Lake in 1994 did not fit the JS models, so that trip data was excluded from the JS modeling.

Overall and individual GOF statistics for the annual JS model indicate homogeneity in capture and survival rates among tag-groups (Table 6). A sign of heterogeneity is seen in the trip-by-trip model data as the “Overall” chi-square was significant at P = 0.03. Inspection of the capture probabilities for each tag group used in the GOF tests shows that the heterogeneity in the trip-by-trip data results from the (on average) higher recapture probabilities of fish captured most frequently (the second tag group in “Chi-square test 2,” Table 7). We see no obvious correction for this sort of deficiency in model fit.

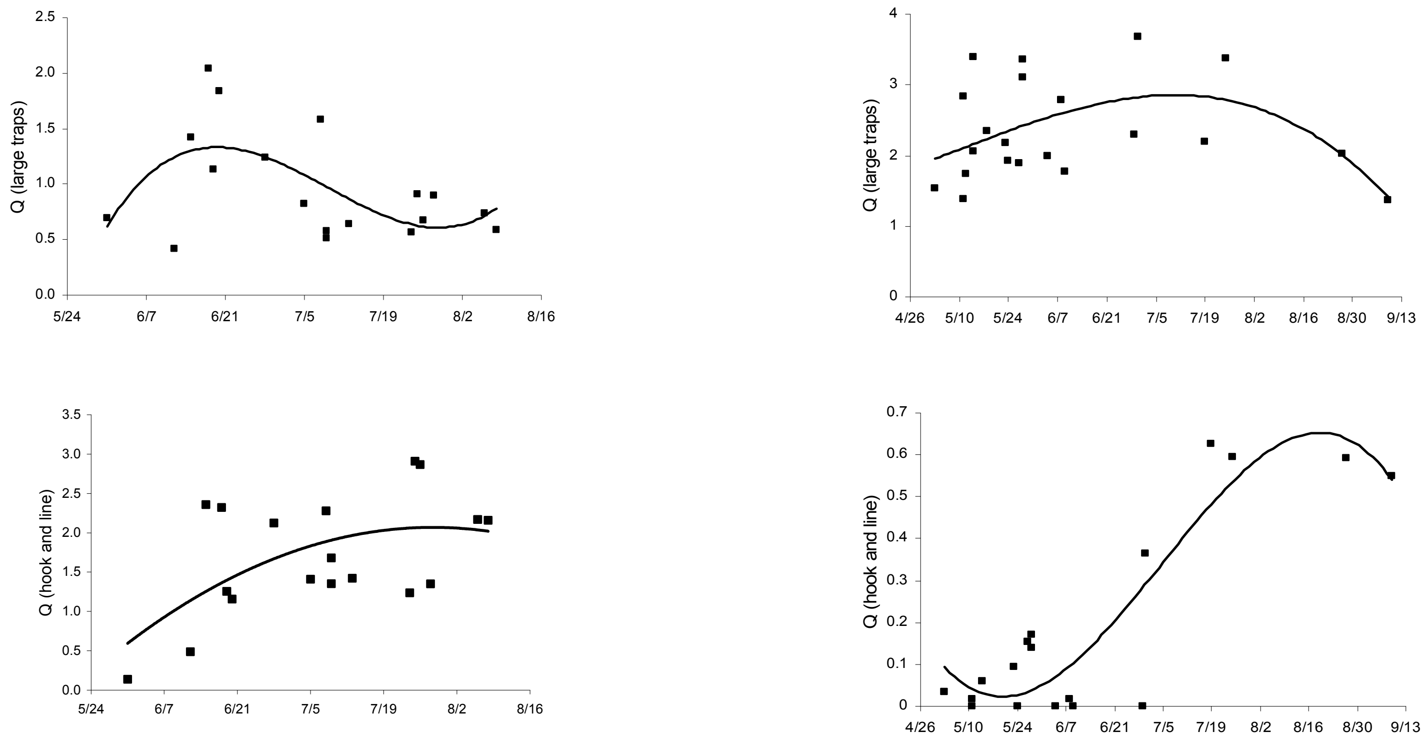

Figure 4.–Catchability (Q = s x cpue/N) for large trap and hook-and-line by sampling date at Turner (left panels) and Baranof (right panels) Lakes. Trends in the data are illustrated with smoothing-lines made with 2nd- and 3rd-order polynomials. Q is scaled up by s = 3,000 for large traps and by s = 1,000 for hook-and-line. Since fishing techniques at Turner Lake in 1994 were somewhat different than those used later, that data has been excluded from the plot.

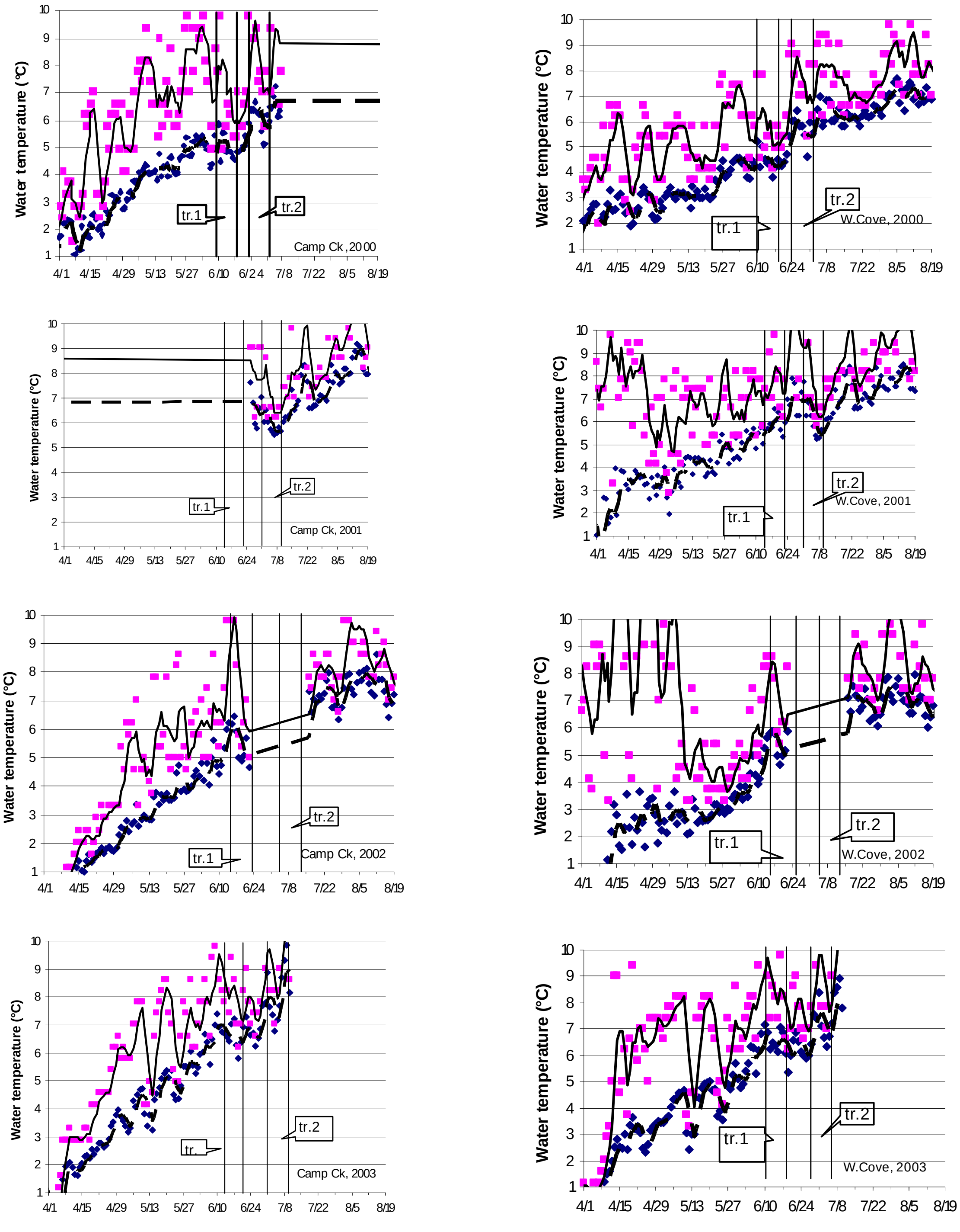

Figure 5.–Mean (dashed line) and maximum (solid line) daily water temperatures in Camp and Wilderness Cove creeks, and timing of 10-day sample trips (tr.1 and tr.2) at Turner Lake 2000–2003. Assuming that temperatures of about 3° to 6°C initiate spawning activity, and actual spawning occurs when daily maximum water temperatures reach 6–9°C (Behnke 1992), the plots suggest a range of possible spawning times relative to sampling dates.

Table 4.–Summary statistics and estimates of abundance of cutthroat trout ≥180 mm FL in Turner Lake based on a 2-event Petersen closed-population model.

	1994	1995	1996	1997	1998
Hypothesis tests: stat (p-value)					
K-S test: Equal length distrib	0.072 (0.991)	0.320 (0.020)	0.191 (0.664)	0.159 (0.266)	0.308 (0.052)
χ2 test: Equal marked fraction	2.98 (0.225)	6.69 (0.035)	0.198 (0.906)	0.163 (0.922)	4.67 (0.097)
χ2 test: Equal recapture rate	3.67 (0.159)	2.97 (0.227)	1.85 (0.396)	2.00 (0.368)	1.78 (0.410)
CP abundance estimate:					
Petersen: N (SE)	2,003 (254)	1,942 (337)	2,207 (506)	1,838 (194)	1,743 (331)
Petersen parameters: M, C, R[a]	290, 302, 43	256, 188, 24	206, 159, 14	164, 601, 53	217, 167, 20
First day of CP sampling events					
First trip	13 Jul	26 Jul	31 May[b]	25 Jul	9 Jul
Second trip	27 Jul	8 Aug	9 Jul	6 Aug	24 Jul
	1999	2000	2001	2002	2003
Hypothesis tests: stat (p-value)					
K-S test: Equal length distrib	0.334 (0.268)	0.175 (0.380)	0.248 (0.302)	0.155 (0.401)	0.159 (0.136)
χ2 test: Equal marked fraction	1.42 (0.492)	1.46 (0.483)	3.03 (0.220)	0.474 (0.789)	4.86 (0.088)
χ2 test: Equal recapture rate	2.47 (0.291)	0.756 (0.685)	0.050 (0.975)	0.182 (0.913)	3.40 (0.183)
CP abundance estimates					
Petersen: N (SE)	1,609 (420)	1,866 (277)	3,575 (785)	1,856 (255)	1,826 (202)
Petersen parameters: M, C, R[a]	76, 229, 10	219, 279, 32	225, 268, 16	251, 279, 37	315, 263, 54
First day of CP sampling events					
First trip	13 Jul	15 Jun	19 Jun	20 Jun	18 Jun
Second trip	28 Jul	28 Jun	5 Jul	8 Jul	5 Jul

[a] M = number marked in event 1, C = number sampled in event 2, R = number marks recovered in event 2.

[b] A second 9-day trip, beginning 12 June, added to first sampling event to increase sample size.

The trip-by-trip JS model indicates mortality or recruitment occurred between our summer sampling trips in most years, and marked intra-annual variation in abundance occurred during the span of our annual samplings, especially in 1996 and 2001 (Table 8). As mortality and recruitment occur between trips, the instantaneous sampling assumption made when we pooled data to make the annual JS model is to some extent violated, and results from the 2-event CP models can appropriately be assigned to specific sample times, as noted below.

Abundance and Survival

Correspondence between the annual and trip-by-trip JS abundance estimates, and the CP abundance estimates at Turner Lake is high (Figure 6, Table 8). The overall GOF test for the trip-by-trip JS model is significant (Table 6), so abundance estimates from the Petersen model could suffer some mild bias from the heterogeneity exposed by this testing.

Average estimated abundance over the experiment is 2,047 fish using the Petersen CP model, which we recommend with the following qualifications. Recruitment between the 2 summer sampling trips in 1997, 2000, and 2001 imply the Petersen CP estimate for these years is germane to the time of the second sampling trip, after the recruitment occurs. Mortality between summer samples in 1995, 1996, 1998, and 2002 imply (assuming marked and unmarked fish die at similar rates) that Petersen estimates in these years are germane to the first sampling trip, prior to the mortality. Significant recruitment and mortality simultaneously occur between the summer samples taken in 1997, so the CP estimate for 1997 should be biased low. The Petersen CP estimates are thus germane to abundance from as early as the first week of June (in 1996) to as late as the first week of August (in 1997), with a median (mid-trip) date of about July 12.

Annual survival rates averaged 0.63, while rates from the last trip in year *t* to the 1st trip in year *t+1* (excluding the constrained estimate of 1.0 from 1995 to 1996) vary from 0.51 to 0.91 and averaged 0.67. Fishing mortality at Turner Lake has been believed to be at or very near zero since 1994 (Appendix A5). However, the U.S. Forest Service (USFS) recreational cabin survey

Table 5.–Summary statistics for annual and trip-by-trip Jolly-Seber models used at Turner Lake, 1994–2003. See key to variables at bottom of table.

Year	Trips	Period	n_i	m_i	R_i	r_i	z_i
Annual model							
1994	1-3	1-3	748	0	748	210	0
1995	1,2	5-6	419	115	407	138	95
1996	1-3	7-9	351	89	349	113	144
1997	1,2	10-11	711	182	706	156	75
1998	1,2	12-13	361	108	347	80	123
1999	1,2	14-15	290	70	276	81	133
2000	1,2	16-17	462	122	456	144	92
2001	1,2	18-19	480	134	472	95	102
2002	1,2	20-21	493	143	487	81	54
2003	1,2	22-23	581	135	580	0	0
Trip-by-trip model							
1994	1	1	290	0	290	125	0
	2	2	300	43	300	109	82
	3	3	269	68	269	87	123
1995	1	5	256	66	256	97	144
	2	6	183	69	171	61	172
1996	1	7	106	21	106	40	212
	2	8	105	30	105	35	222
	3	9	159	57	157	57	200
1997	1	10	429	129	428	146	128
	2	11	358	129	354	86	145
1998	1	12	222	69	220	61	162
	2	13	159	59	147	39	164
1999	1	14	153	36	145	51	167
	2	15	154	51	148	47	167
2000	1	16	220	63	219	94	151
	2	17	274	91	269	82	154
2001	1	18	231	70	225	63	166
	2	19	265	80	263	48	149
2002	1	20	251	70	247	69	127
	2	21	279	110	277	49	86
2003	1	22	316	77	315	53	58
	2	23	318	111	318	0	0

Key: ni = number of fish caught in sample i; mi = number of marked fish caught in sample i; Ri = number returned to the population alive with marks from sample i; ri = number caught in sample i which are recaptured later; zi = number not caught in sample i which were previously captured and are recaptured later.

(Harding et al. 2005) for 2002 estimated a harvest of 251 cutthroat trout despite regulations prohibiting the retention of trout. Because catch-and-release mortality is thought to be low (about 5%; Wright 1992), the estimated survival rates in all other cases surely approximate natural survival rates.

Age, Length, and Abundance-at-Length

The distribution of cutthroat trout ≥180 mm FL in Turner Lake is dominated by the 240 to 260 mm FL size class with approximately 10% of the population being larger than 340 mm FL (Figure 7). Annual variation in the distribution of lengths is considerable (Appendix B2, Appendix A6). The size distribution of fish captured with all gear type varies somewhat from that for fish captured using only HL (Appendix B3), but only in the smallest size classes. This reinforces our view that large fish are not under-represented in these data sets.

Age 4 was the most common age class observed at Turner Lake, and age 9 is the oldest read in our samples (Figure 8, Appendix A7, and Appendix B4). Again, annual variation in the distribution of ages is considerable (Appendix A7). As expected, considerable annual variation in the estimated number of trout in each length class was also found (Appendix A8). Summing the number in the largest size classes across the span of this experiment shows considerable increase in the number of fish >300 mm FL, but less change in the number of very large fish >380 mm FL (Figure 9).

On average, approximately 51% of cutthroat trout in Turner Lake were larger than the regionwide minimum size limit of 11 in (260 mm FL) and would be available for legal harvest (Appendix A8); the current sport fish regulation in Turner Lake however prohibits any retention of cutthroat trout. Approximately 10% were ≥14 inches (335 mm FL; high-use minimum size limit) and 0.5% (<10 fish) were >20 inches and would classify as a "trophy" under the ADF&G Trophy Fish Program.

Agreement between the 2 independent (replicate) age readings at Turner Lake was 73% (range 68–77%). Approximately 3% of the scales randomly selected for aging were either regenerated or otherwise unreadable. Comparing ages read from scales of tagged fish to estimates of the "true age" of the tagged fish suggested significant bias was present in our readings of older fish (Figure 10). We could not calculate realistic, unbiased age composition estimates from our observed ages due to the high bias and imprecision encountered.

Table 6.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities for the Jolly-Seber models used at Turner Lake, 1994–2003. Overall chi-squares are the sum of the individual test statistics.

			Test 1[a]		Test 2[a]	
Year	Trips	Period	Chi-square	P-value	Chi-square	P-value
Annual model						
1994	1-3	1–3	–	–	–	–
1995	1,2	5–6	0.743	0.389	–	–
1996	1-3	8–9	0.431	0.511	7.048	0.030
1997	1,2	10–11	2.346	0.126	0.480	0.787
1998	1,2	12–13	0.247	0.619	0.196	0.907
1999	1,2	14–15	<0.001	>0.999	1.538	0.464
2000	1,2	16–17	0.537	0.464	1.609	0.447
2001	1,2	18–19	0.925	0.336	1.618	0.445
2002	1,2	20–21	0.433	0.511	2.619	0.270
2003	1,2	22–23	–	–	–	–
Overall χ^2: By test			5.66 (8 df)	0.685	15.11 (14 df)	0.371
Both tests			20.77 (22 df)	0.535		
Trip-by-trip model						
1994	1	1	–	–	–	–
	2	2	4.772	0.029	–	–
	3	3	0.814	0.367	3.963	0.138
1995	1	5	0.088	0.767	3.708	0.157
	2	6	0.823	0.364	5.400	0.067
1996	1	7	3.893	0.049	0.440	0.507
	2	8	0.840	0.359	0.511	0.475
	3	9	0.054	0.817	0.598	0.742
1997	1	10	0.137	0.711	1.189	0.552
	2	11	0.126	0.723	6.644	0.036
1998	1	12	1.255	0.263	1.044	0.593
	2	13	1.906	0.167	2.896	0.235
1999	1	14	0.702	0.402	5.998	0.050
	2	15	1.085	0.298	9.774	0.008
2000	1	16	0.239	0.625	3.296	0.193
	2	17	0.588	0.443	1.146	0.564
2001	1	18	0.263	0.608	1.438	0.487
	2	19	0.041	0.840	7.501	0.024
2002	1	20	0.031	0.861	2.044	0.360
	2	21	0.001	>0.999	0.464	0.793
2003	1	22	0.963	0.327	0.792	0.673
	2	23	–	–	–	–
Overall χ^2: By test			18.62 (20 df)	0.547	58.84 (36 df)	0.01
Both tests			77.46 (56 df)	0.030		

[a] Test 1 is a 2 x 2 contingency table with 1 df; test 2 is 2 x 3 table with 2 df.

Maximum Sustained Yield

Abundance at Turner Lake was stable over this 10 year study (Figure 6). Harvests were relatively small (average 4% of abundance, Appendix A5) and the inter-annual variation in abundance we saw appears largely a result of natural changes in survival and recruitment. Using the CP abundance estimates and ADF&G cabin survey harvest statistics, *MSY* is 248 fish, or 12% of average abundance over 180 mm FL (Table 9).

BARANOF LAKE

Capture, Tagging and Recovery

A total of 16,582 cutthroat trout ≥180 FL were captured in Baranof Lake between 1994 and 2003, most (90%) were caught using LT (Table 10). An

Table 7.–Capture probabilities by tag-group and sampling trip for 2 goodness-of-fit tests based on the Jolly-Seber models used at Turner Lake, 1994–2003. See Table 6 for companion summary statistics.

		Chi-square test 1[a]		Chi-square test 2[b]		
Year	Trips	First captured before sample *i*	First captured in sample *i*	First captured before *i* –1, and not captured in *i* –1	First captured before *I* –1, and captured in *i* –1	First captured in *i* –1
Annual model						
1994	1-3	–	–	–	–	–
1995	1,2	0.30	0.35	–	–	–
1996	1-3	0.30	0.33	0.35	0.59	0.35
1997	1,2	0.18	0.23	0.69	0.69	0.74
1998	1,2	0.25	0.22	0.45	0.50	0.47
1999	1,2	0.29	0.29	0.37	0.35	0.28
2000	1,2	0.29	0.33	0.56	0.70	0.54
2001	1,2	0.17	0.21	0.61	0.49	0.56
2002	1,2	0.15	0.17	0.75	0.83	0.67
2003	1,2	–	–	–	–	–
Mean		0.24	0.27	0.54	0.59	0.51
Trip-by-trip model						
1994	1	–	–	–	–	–
	2	0.51	0.34	–	–	–
	3	0.37	0.31	0.34	0.55	0.32
1995	1	0.36	0.38	0.28	0.48	0.31
	2	0.31	0.38	0.34	0.25	0.19
1996	1	0.19	0.42	0.08	0.17	0.12
	2	0.40	0.31	0.12	0.50	0.08
	3	0.38	0.36	0.23	0.17	0.17
1997	1	0.33	0.35	0.52	0.43	0.44
	2	0.23	0.25	0.41	0.64	0.47
1998	1	0.33	0.25	0.29	0.38	0.28
	2	0.33	0.22	0.24	0.41	0.28
1999	1	0.41	0.33	0.21	0.11	0.00
	2	0.37	0.29	0.20	0.57	0.24
2000	1	0.40	0.44	0.30	0.42	0.18
	2	0.27	0.32	0.39	0.40	0.32
2001	1	0.26	0.29	0.29	0.40	0.28
	2	0.19	0.18	0.39	0.44	0.18
2002	1	0.27	0.28	0.34	0.27	0.45
	2	0.18	0.18	0.57	0.58	0.52
2003	1	0.13	0.18	0.59	0.58	0.50
	2	–	–	–	–	–
Mean		0.31	0.30	0.32	0.41	0.28

[a] prob (recaptured again, given captured in event *i*) as function of stated first capture history.

[b] prob (captured in event *i*, given captured in events *i* or beyond) as function of stated first capture history.

additional 3,406 cutthroat trout <180 mm FL were also captured (Appendix A9). Catches were made by fishing 8 to 22 (average 17) LT per day and HL fishing 0 to 3.9 (average 1.6) rod-hours per day during each 10-day sampling trip. CPUE and catchability for LT was mildly dome-shaped over time while CPUE and catchability for HL increased steeply from early-June through early August (Figure 4, Appendix A10). Because of these temporal trends at Baranof Lake, HL effort only contributed significantly to the experiment during a few sampling trips. The overall annual tag loss at Baranof Lake averaged 6.6%, and ranged from 1.9 % (1994) to an estimated 14.3% in 1995 (Table 11). The tag-loss rate for 1994 is uncertain due to a procedural error during the final (third) sampling trip when an unknown number of fish (approximately 500) were given an adipose finclip but were not anchor T-bar tagged (Table 1).

Table 8.–Estimates of abundance (N), survival (ϕ), and births (B) of cutthroat trout ≥180 mm FL at Turner Lake from the constrained Jolly-Seber model.

Year	Trips	Period	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\varphi})$	$\hat{B}$	$SE(\hat{B})$
				Annual model				
1994	1–3	1–3	–	–	0.527[a]	0.044	–	–
1995	1,2	5–6	1,426	145	0.774	0.077	982	210
1996	1–3	7–9	2,077	249	0.657	0.067	659	170
1997	1,2	10–11	2,022	193	0.610	0.070	884	199
1998	1,2	12–13	2,114	270	0.593	0.078	883	247
1999	1,2	14–15	2,128	300	0.568	0.064	350	164
2000	1,2	16–17	1,551	157	0.853	0.094	950	202
2001	1,2	18–19	2,268	272	0.477	0.064	516	138
2002	1,2	20–21	1,593	200	–	–	–	–
2003	1,2	22–23	–	–	–	–	–	–
				Trip-by-trip model[b]				
1994	1	1	–	–	0.927	0.092	–	–
	2	2	1,875	307	0.853	0.095	175	281
	3	3	1,773	247	0.685	0.077	488	171
1995	1	5	1,702	171	0.831	0.089	0[c]	na[c]
	2	6	1,414	158	1.000[c]	na[c]	1062	222
1996	1	7	2,464	257	0.957	0.149	0[c]	na[c]
	2	8	2,357	370	0.800	0.135	0[c]	na[c]
	3	9	1,885	258	0.712	0.086	336	157
1997	1	10	1,677	167	0.904	0.098	500	175
	2	11	2,014	238	0.687	0.095	721	237
1998	1	12	2,102	314	0.842	0.142	57	250
	2	13	1,825	314	0.660	0.114	777	223
1999	1	14	1,974	274	0.939	0.149	0[c]	na[c]
	2	15	1,846	284	0.627	0.083	321	182
2000	1	16	1,474	183	1.000[c]	na[c]	268	200
	2	17	1,741	169	0.909	0.094	691	259
2001	1	18	2,269	305	1.000[c]	na[c]	528	329
	2	19	2,791	331	0.506	0.064	390	166
2002	1	20	1,800	193	0.857	0.134	0[c]	na[c]
	2	21	1,539	225	0.553	0.099	882	209
2003	1	22	1,731	293	–	–	–	–
	2	23	–	–	–	–	–	–

[a] Survival or birth rate between event i and event $i + 1$

[b] Estimation constrained to admissible values (Schwarz and Arnason 1996).

[c] Constrained value; SE for constrained value not available.

Water Temperatures

Camp Creek and Main Inlet stream temperatures were generally below those in South Creek, which enjoyed a southern exposure and increased solar radiation (Table 12). Average temperature at mid-lake was generally between that measured at the cooler and warmer inlet streams. Assuming temperatures of 6° to 9°C are favorable for spawning, our sampling dates likely preceded or overlapped spawning in some streams in most years (Figure 11).

Mark–Recapture-CP Model

Size-selective sampling was not apparent in 7 of 9 years (Appendix B5, Table 13). In contrast to the small number of recaptures annually at Turner Lake, recapture rates at Baranof Lake were high (average 75 fish/year). Given the widespread indications that our gear is not size selective, we concluded that adjusting for occasional, possible selectivity was unwarranted in this analysis.

Stratified (Darroch) CP models of abundance were suggested in 6 of 9 years by the chi-square

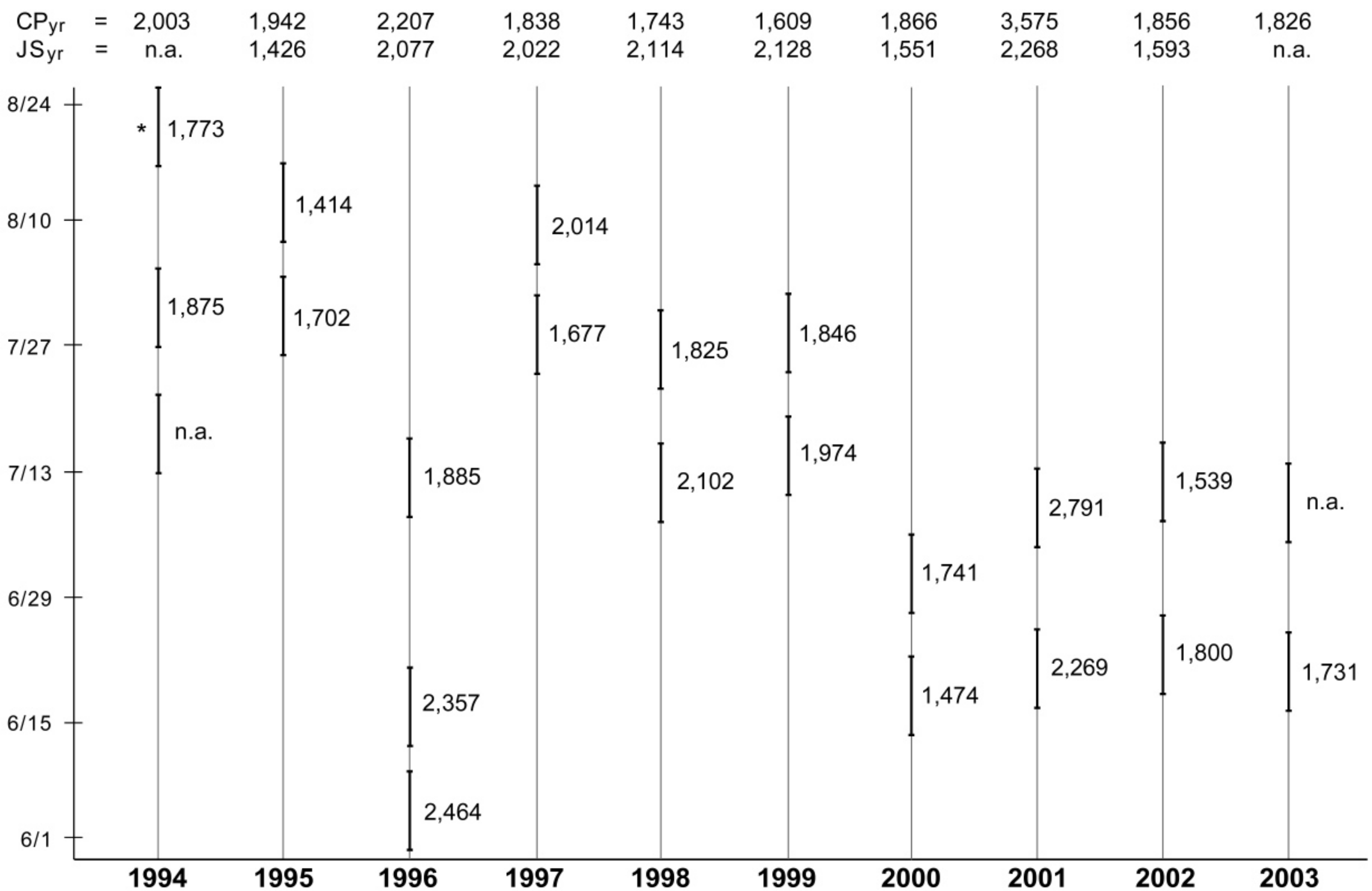

Figure 6.–Abundance estimates of cutthroat trout ≥180 mm FL at Turner Lake under 3 experimental designs. The vertical bars over each year on the abscissa denote the span of individual sampling trips. Jolly-Seber (JS) estimates of abundance for each trip are shown just right of each bar. Annual JS estimates derived from pooling data from all sampling, and closed population (CP) estimates based on the first 2 sampling trips each year, are tabulated over each column. Estimates for CP experiments were computed using data summaries compiled for the trip-by-trip JS analysis (trips marked with stars excluded), and thus may differ from those in previous analysis.

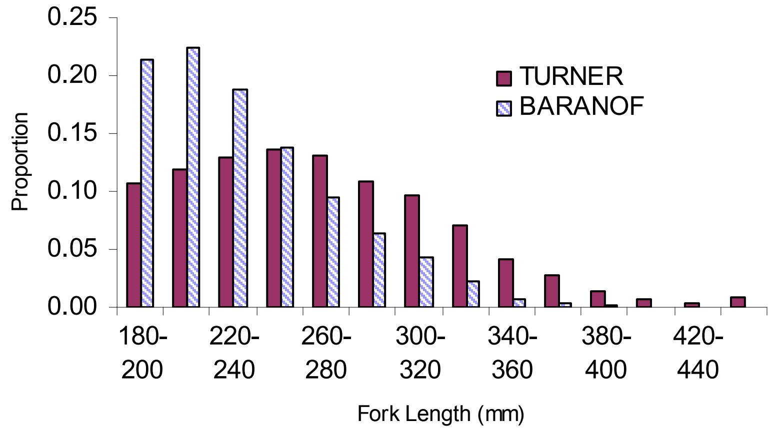

Figure 7.–Average length composition of cutthroat trout ≥180 mm FL at Turner and Baranof Lakes, 1994–2003. Estimates are based on data collected in mid- to late-May at Baranof Lake and in July in Turner Lake.

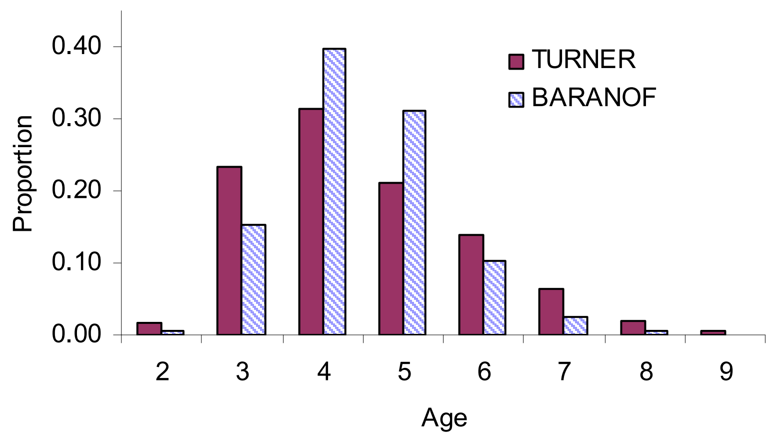

Figure 8.–Average age composition of cutthroat trout ≥180 mm FL at Turner Lake (1995–2001) and Baranof Lake (1994, 1998, and 2003). Estimates are based on data collected from June through August for Turner Lake, and in mid-May for Baranof Lake.

tests used to evaluate the equal probability of capture assumption (Table 13). Except in 1994, the suggested estimates of abundance are fairly steady (average 7,700; range 5,616 to 8,894). The Darroch estimate for 1994 was very large and imprecise (20,961 ± 5,579) relative to estimates for other years and the Darroch estimate of 12,186 ± 888 for 1994 produced from the original analysis of these data[2] by Der Hovanisian and Marshall (1995). Further analysis of the m-r data in Der Hovanisian and Marshall (1995) shows an unstratified Petersen model would be supported by the diagnostic testing procedure used in our analysis, and such an estimate (11,456, SE = 593) is similar to both the original Darroch estimate (12,186) and our Petersen estimate (12,511). While the reason for the relatively high Darroch estimate for 1994 from this analysis is unknown, all other estimates are much more precise and near 12,000 fish, and together seem much more likely than the value near 21,000 from our Darroch model. Thus, we recommend our unstratified Petersen estimate of 12,511, SE = 1,059 for 1994 (Table 13).

[2] Using fish sampled in trips 1-3; see Table 1.

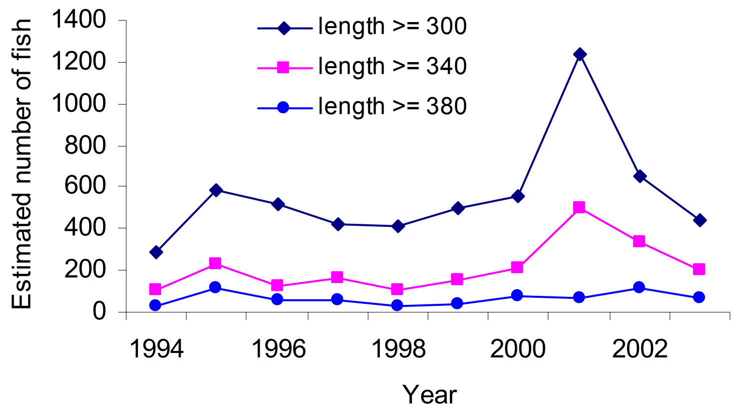

Figure 9.–Estimated number of cutthroat trout greater than 300 mm, 340 mm, and 380 mm FL in Turner Lake, 1994–2003. The slow increase is probably a result of the very restrictive harvest regulations over this period.

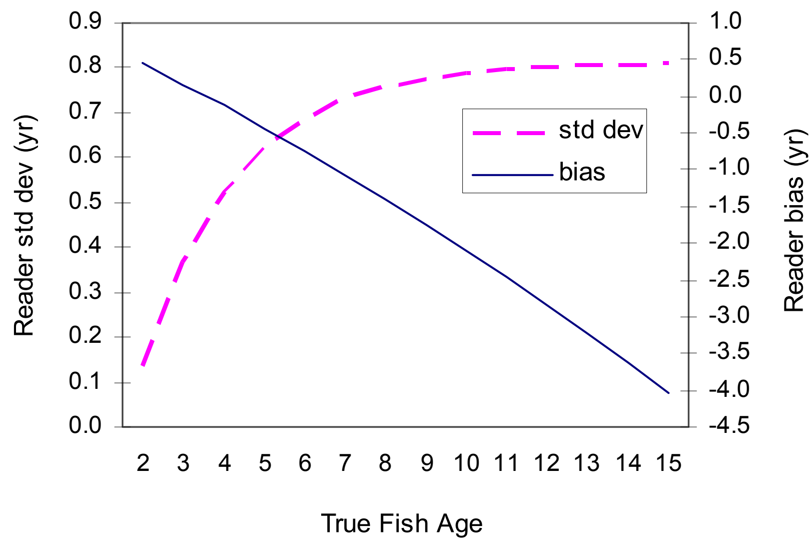

Figure 10.–Estimates of bias and precision for aging cutthroat trout from scales at Turner Lake in this study. The oldest age at Turner Lake (based on tag-recovery information and estimates of age at first capture) is about 14. The oldest reading from a scale at Tuner Lake in this study was 9. The plot shows, for example, that we expect ages read from an 11 year old fish to be biased by about -2.8 years (reader under-estimates age) and to have a precision (SD) of about 0.8 years.

Mark–Recapture-JS Models

Summary statistics for the 23-trip JS model (Table 14) show the large sample sizes obtained in each sampling period with an average of 13% of the estimated population (range 7% to 19%) sampled during the individual trips.

GOF tests for both JS models indicate significant heterogeneity in capture and survival rates (Table 15). Individual and mean capture probabilities for each tag group (Table 16) tend to be lower on average for fish first captured (the second tag group in chi-square test 1, Table 16), and higher on average for fish captured most frequently (the second tag group in chi-square test 2).

The high statistical significance of chi-square test 1 for both JS models ($P < 0.002$, Table 15) and the low average capture probability for newly-tagged fish relative to previously-captured fish (18% lower in annual data, 26% lower in trip data, Table 16) suggest the generalized JS model, which accounts for a 1-period effect of handling and tagging, is more appropriate for modeling these data than is the standard JS model. This conclusion was supported, though weakly, by the GOF test results from fitting both the full and generalized JS models to the data (annual data: $P = 0.002$ for the full model versus $P = 0.04$ for the generalized model; trip data: $P < 0.00001$ for the full model versus $P = 0.001$ for the generalized model, Table 15).

Estimated abundance (using the modified JS model in POPAN) varies approximately by a factor of 2 between and within years (Table 17). Recruitment typically peaked between the last trip of each year and first trip the following year. Significant recruitment also occurred between sampling trips in 1995 when sampling continued into September, and during 1999, 2000, and 2001. Similarly, survival was lowest between the final trip of each year and the first trip next year. Survival estimates, however, are significantly less than 1.0 between closely spaced trips in some sampling years (e.g., 1995, 1996, 1998, 2000, and 2001), which we would not expect.

Abundance and Survival

All diagnostic indicators applied to the CP and JS models for Baranof Lake suggest the more complex available models (i.e., the Darroch CP model or the generalized JS model). Pooling data across widely separated sampling dates appears unwise. The high recruitment and loss rates between adjacent samples within a year (Figure 12, Table 17) suggest the entire population was not sampled during each trip; for example, some fish in deep water and/or some spawning fish were unavailable to our gear on a given occasion. This conclusion is similar to that reached by Rosenkranz et al. (1999) for samples collected at Florence Lake. In this situation we believe the CP abundance estimates are most indicative of the true total abundance in the lake.

Survival estimates for new and previously-captured fish in this experiment were also calculated using the generalized JS model in JOLLY (Table 18). Because newly-marked fish appeared the worse from initial handling and tagging, survival rate estimates for previously-marked fish are better indicators of survival rates for unmarked fish in the lake (the rates of biological interest). The average annual natural survival rate for previously captured fish **(**Table 18) is $\phi = 0.52$ (SE = 0.12). Because fishing and mortality at Baranof Lake has been very low since 1994 (Appendix A5) and catch-and-release mortality is thought to be low (about 5%; Wright 1992), the estimated survival rates are not far from the natural survival rates (more on this below).

Age, Length, and Abundance-at-Length

The distribution of cutthroat trout ≥180 mm FL in Baranof Lake is skewed to the right of (larger than) the most commonly sized fish (almost half, 44%), are smaller than 220 mm FL and only 7.5% of the population is longer than 300 mm FL (Figure 7). Annual variation in the distribution of lengths is considerable (Appendix B6, Appendix A11).

Age 4 was the most commonly observed age class at Baranof Lake, and age 8 was the oldest read in our samples (Figure 8, Appendix A12, and Appendix B7). The annual variation in the estimated number of trout in each length-class is obvious, presumably the result of fluctuating recruitments of young age classes (Appendix A13). Inspection of the number in the largest size classes across the span of this experiment shows considerable decline in the number of fish >280 mm FL, but very little change in the number of fish >340 mm FL (Figure 13).

Agreement between the 2 independent (replicate) age readings at Baranof Lake was 43% (range 32–51%). Fish ages at Baranof Lake were more difficult to estimate from scale patterns than they were at Turner Lake, and comparisons between estimated and “true” ages at Turner Lake showed that estimates became very biased (low) as fish age increased. We thus conclude our age estimates at Baranof Lake suffer similar bias as estimated age increases.

Table 9.–Parameters and calculations leading to estimates of MSY for cutthroat trout ≥180 mm FL at Turner Lake. Average abundance over years ($\overline{N}$) is taken to be lake carrying capacity K. ADF&G cabin survey (Cabins) estimates of harvest are believed superior to the ADF&G Statewide Harvest Survey (SWHS) alternative. MSY for Turner Lake is estimated at 248 fish ≥180 mm FL.

	N	*H*		*S* =	*Z*=-ln(*S*)	*A* = 1-exp(-*Z*)	*F* = *Z* / *A* * *H* / *N*	*M* = *Z* - *F*	*MSY*	*r* = 1.2 *M*
	Petersen	Cabins	SWHS	Annual	Inst ann tot	Annual	Inst ann (Cabin)	Inst ann	=0.3 **M** *K*	Inst rate of
Year	CP	harvest	harvest	survival	mort rate	mort rate	harv mort rate	nat mort rate	*K* = Ave CP	increase
1994	2,003	88	53	0.527	0.641	0.473	0.059	0.581	349	0.70
1995	1,942	57	0	0.774	0.256	0.226	0.033	0.223	130	0.27
1996	2,207		0	0.657	0.420	0.343				
1997	1,838		0	0.610	0.494	0.390				
1998	1,743		0	0.593	0.523	0.407				
1999	1,609	58	0	0.568	0.566	0.432	0.047	0.518	250	0.62
2000	1,866		0	0.853	0.159	0.147				
2001	3,575		0	0.477	0.740	0.523				
2002	1,856	251	0							
2003	1,826		0							
Ave	2,047	114	5	0.632	0.475	0.368	0.047	0.441	243	0.53
F, M, MSY, and r based on averages of N, H, Z, A over years =							0.072	0.403	248	0.48

Table 10.–Catch of cutthroat trout ≥180 mm FL by gear type and trip at Baranof Lake.

							Total	
Year	Trip	Period	Large trap	Hoop net	Hook & line	Troll	Trip	Year
1994	1	1	656	352	0		1,008	2,450
	2	2	677	744	21		1,442	
1995	1	3	1,005		6		1,011	3,105
	2	4	882		17		899	
	3	5	534		99		633	
	4	6	466		96		562	
1996	1	7	743		1	1	745	1,119
	2	8	374		0	0	374	
1997	1	9	668		0		668	1,180
	2	10	504		8		512	
1998	1	11	618		2		620	1,345
	2	12	719		6		725	
1999	1	13	664		0		664	1,611
	2	14	947		0		947	
2000	1	15	720		0		720	2,112
	2	16	738		0		738	
	3	17	534		120		654	
2001	1	18	659		0		659	2,286
	2	19	1,000		1		1,001	
	3	20	509		117		626	
2002	1	21	562		31		593	593
2003	1	22	449		0		449	781
	2	23	222		110		332	
Total			14,850	1,096	635	1	16,582	16,582

Table 11.–T-bar tag loss at Baranof Lake, 1994–2003.

Year	Tag loss rate (%)[a, b]
1994	1.9
1995	10.3–14.3
1996	7.6–9.6
1997	8.8–10.2
1998	5.9–6.9
1999	5.8
2000	4.8
2001	6.3
2002	4.1
2003	7.0

[a] All cases an anchor T-bar tag appeared to be lost.

[b] Minimum and maximum rates (see text for details).

On average, approximately 24% of cutthroat trout in Baranof Lake were larger than the regionwide minimum size limit of 11 in (260 mm FL) but only about 1% of the populations was ≥14 in (356 mm FL) and available for legal harvest under the high-use minimum size limit regulation in place at Baranof Lake (Appendix A13).

Maximum Sustained Yield

Abundance did not trend up or down noticeably over this 10-year study (Figure 12). As at Turner Lake, harvests were relatively small (average 2.5% of abundance, Appendix A5) and occurred after the annual m-r samplings were complete. The inter-annual variation in abundance we saw at Baranof Lake appears largely a result of natural changes in survival and recruitment. We thus assume the carrying capacity (or maximum equilibrium population, *K*) of Baranof Lake during this 10-year study was near the observed average population size. Using the annual CP estimates, the best annual survival estimates (Table 18), and SWHS harvest statistics, *MSY* is 1,575 fish, 19% of the population over 180 mm FL (Table 19). The SWHS harvest estimates were used for the Baranof *MSY* analysis because the number of anglers accessing the lake via trail from the community of Baranof Warm Springs (i.e., not reserving the USFS cabin) increased as Baranof Warm Springs became a tourist destination.

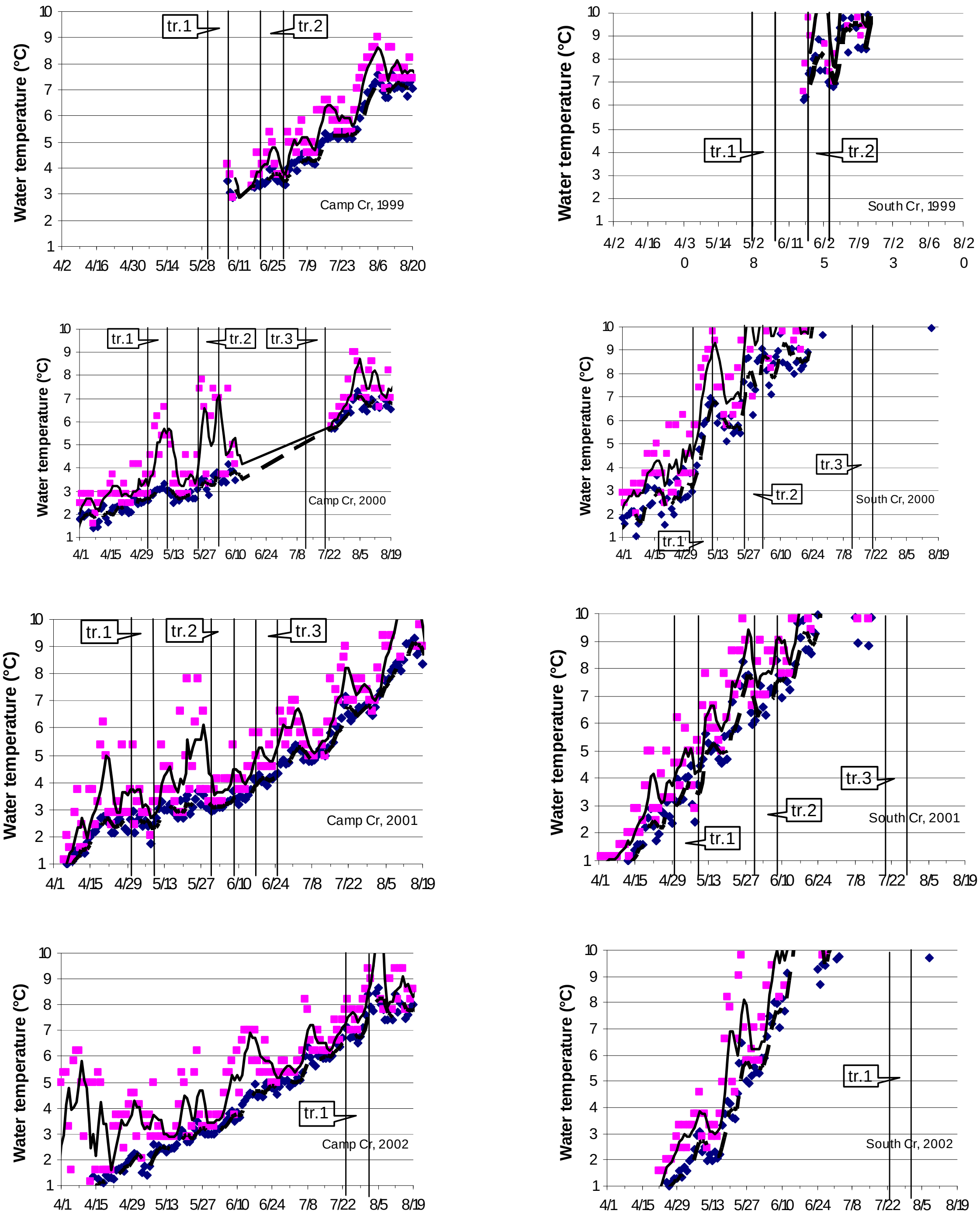

Figure 11.–Mean (dashed line) and maximum (solid line) daily water temperatures in Camp and South creeks, and timing of 10-day sample trips (tr.1 and tr.2) at Baranof Lake 1999–2003. Assuming that temperatures of about 3 to 6°C initiate spawning activity, and actual spawning occurs when daily maximum water temperatures reach 6–9°C (Behnke 1992), the plots suggest a range of possible spawning times relative to sampling dates.

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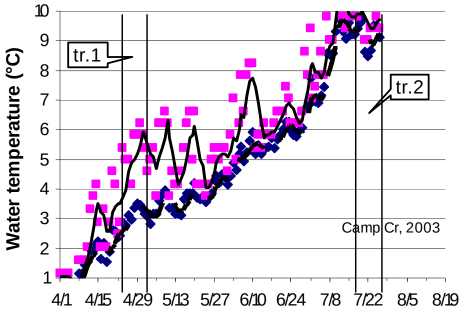
Figure 11.–Page 2 of 2.



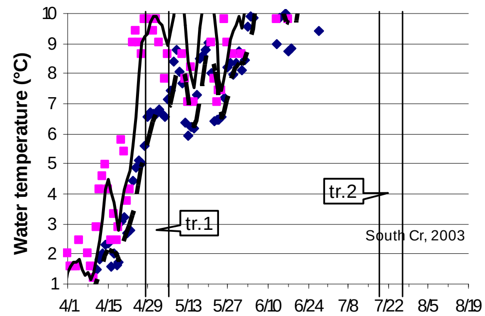


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Table 12.–Average daily water temperature (°C) at four recording sites during each 10-day sample trip, Baranof Lake, 1999–2003.

Start Date of sample trip	Main inlet	Camp Creek	South Creek	Mid-lake
June 25, 1999	4.1	3.8	8.1	5.3
May 10, 2000	3.8	2.8	6.2	6.2
May 31, 2000	4.6	3.7	8.4	8.3
July 15, 2000	N/A	N/A	12.9	9.9
May 8, 2001	3.1	2.8	4.6	4.3
June 5, 2001	3.9	3.4	7.5	7.2
July 21, 2001	6.3	6.7	13.0	10.7
July 25, 2002	5.7	7.2	12.6	9.9
May 6, 2003	4.7	3.5	7.2	7.8
July 21, 2003	7.8	9.0	13.4	13.2

Uncertainty in estimating abundance at Baranof Lake does suggest caution when using this estimate of *MSY*. For example, if annual JS abundance estimates for the same years are used instead of the CP estimates, *MSY* would be lower by about 275 fish (23%).

DISCUSSION

This report summarizes a 10-year study on resident cutthroat trout in 2 lakes in Southeast Alaska that have barriers to anadromous populations. Both lakes are remote from human populations and experienced significant sport fishing pressure prior to the initiation of this study.

Turner Lake was once known for its yield of trophy-size fish. Anecdotal information suggests catch rates were declining at Turner Lake in the late 1970s (Jones et al. 1990); at that time (1977–1981) the 5-year average cutthroat trout harvest at Turner Lake was 488 fish (Jones et al. 1990). Angler reports of "regular harvests" of many very large (>18 in FL) fish from the late 1940s are known (Figure 14). Today, we estimate that <0.5% of the population (=10 fish) are >18.1 in FL (460 mm) in length (Appendix A6). The demise of the trophy fishery at Turner Lake led to catch-and-release regulations and the initiation of this study. Small harvests (generally <100 fish) and catch-and-release mortality still occur. Baranof Lake was known for its high production (5-year average harvest 1990–1994 also was 488, Appendix A5) and easy access from Warm Springs Bay (a popular moorage) and proximity to a hot spring.

The long-term goal of this project was to estimate *MSY* at these locations through annual monitoring

Table 13.–Summary statistics and estimates of abundance of cutthroat trout ≥180 mm FL in Baranof Lake based on a 2-event closed-population (CP) models.

	1994	1995	1996	1997	1998
Hypothesis tests: stat (p-value)					
K-S test: Equal length distrib	0.067 (0.726)	0.173 (0.002)	0.134 (0.412)	0.103 (0.510)	0.069 (0.887)
$\chi 2$ test: Equal marked fraction	28.9 (<0.001)	27.2 (<0.001)	5.01 (0.082)	8.17 (0.017)	20.0 (<0.001)
$\chi 2$ test: Equal recapture rate	11.6 (0.003)	20.3 (<0.001)	5.72 (0.057)	7.47 (0.024)	2.40 (0.300)
CP abundance estimates:					
Petersen: N (SE)	12,511 (1,059)[a]	--	--	--	5,616 (573)
Darroch: N (SE)	--	8,624 (1,266)	7,282[b] (1,481)	6,234[b] (1,070)	--
Petersen parameters: M, C, R[c]	994, 1420, 112	985, 857, 131	726, 363, 44	658, 502, 64	563, 736, 73
First day of CP sampling events					
First trip	10 May	10 May	7 May	14 May	29 Apr
Second trip	25 May	25 May	20 May	23 May	19 May
	1999	**2000**	**2001**	**2002**	**2003**
Hypothesis tests: stat (p-value)					
K-S test: Equal length distrib	0.092 (0.644)	0.096 (0.487)	0.184 (0.009)	na	0.259 (0.273)
$\chi 2$ test: Equal marked fraction	11.4 (0.003)	15.4 (<0.001)	21.9 (<0.001)	na	0.910 (0.640)
$\chi 2$ test: Equal recapture rate	1.02 (0.600)	4.62 (0.099)	5.08 (0.079)	na	1.294 (0.524)
CP abundance estimates:					
Petersen: N (SE)	8,894 (983)	--	--	na	8,739 (2,028)
Darroch: N (SE)	--	7,633 (1,222)	8,581 (1,289)	na	--
Petersen parameters: M, C, R[c]	644, 923, 66	702, 731, 80	650, 982, 89	na	436, 319, 15
First day of CP sampling events					
First trip	5 Jun	10 May	8 May	na	6 May
Second trip	25 Jun	31 May	5 Jun	na	21 Jul

[a] Darroch estimate of 20,961 (SE=5,579) indicated by chi-square tests rejected; see text for explanation.

[b] MLE model estimable after pooling data; marking data from areas A and B pooled.

[c] M = number marked in event 1, C = number sampled in event 2, R = number marks recovered in event 2.

of abundance, size, and age composition of the populations. Also, we thought the contrast between results from relatively high (Baranof) and low (Turner) production cutthroat trout systems would help us and other researchers guess when harvests at other non-anadromous lake populations of cutthroat trout in Southeast Alaska might be excessive. Because *MSY* is theoretically pinned to biomass, and the size of cutthroat trout is highly variable among lakes in Southeast Alaska, we would not quickly extrapolate to lakes with very different size distributions.

Despite some difficulties, results are enlightening and raise interesting questions. At Turner Lake, the abundance of fish ≥180 mm FL did not tend to increase over time (1994–2003) even though anglers have been prohibited from harvesting cutthroat trout since 1991. Similarly, while the size composition of the population at Turner Lake during this study may have shifted upward in some length categories (Figure 9), inter-annual variation in the length composition is much more pronounced than are increases in the relative abundance of large fish (Appendix B3). Reliable estimates of the overall age composition, even at Turner Lake where aging was thought to be easiest, could not be obtained due to high imprecision and bias in estimating age for older fish. Still, *MSY* could be estimated by noting that abundance over the 10 years of this study was stable at about 2,000 fish ≥180 mm FL, and was thus likely near its current carrying capacity *K*. In this large, cold, deep, steep-sided lake where trout have a relatively high annual survival rate (average about 0.63), our estimate of *MSY* (248 fish ≥180 mm FL) is but 12% of the population (fish ≥180 mm).

Because there are no studies documenting the size composition of trout at Turner Lake prior to the demise of the trophy fishery, we can hardly speculate what the abundance of trophy-sized fish might once have been, or whether anglers might have been very efficient at capturing trophy-sized fish (see again Figure 14). Distributions of cutthroat sampled much later in 1988 and 1989 (Figure 8 in Jones et al. 1990), and in 1991

Table 14.–Summary statistics for annual and trip-by-trip Jolly-Seber models used at Baranof Lake, 1994–2003. See key to variables at bottom of table.

Year	Trips	Period	n_i	m_i	R_i	r_i	z_i
			Annual model				
1994	1,2	1–2	2,291	0	2,291	457	0
1995	1–4	3–6	2,656	349	2,656	474	108
1996	1,2	7–8	1,045	280	1,045	195	302
1997	1,2	9–10	1,095	274	1,095	205	223
1998	1,2	11–12	1,222	219	1,222	235	209
1999	1,2	13–14	1,500	233	1,500	344	211
2000	1–3	15–17	1,897	368	1,897	344	187
2001	1–3	18–20	2,042	437	2,042	184	94
2002	1	21	564	163	564	58	115
2003	1,2	22–23	733	173	733	0	0
			Trip-by-trip model				
1994	1	1	994	0	994	281	0
	2	2	1,409	112	1,409	288	169
1995	1	3	985	154	985	317	303
	2	4	857	238	857	250	382
	3	5	611	176	611	144	456
	4	6	555	133	555	115	467
1996	1	7	726	181	726	164	401
	2	8	363	143	363	75	422
1997	1	9	658	163	658	163	334
	2	10	501	175	501	106	322
1998	1	11	592	117	592	159	311
	2	12	701	173	701	147	297
1999	1	13	644	106	644	197	338
	2	14	922	193	922	213	342
2000	1	15	702	154	702	213	401
	2	16	726	200	726	173	414
	3	17	643	188	643	132	399
2001	1	18	649	164	649	139	367
	2	19	979	250	979	161	256
	3	20	611	220	611	81	197
2002	1	21	564	163	564	58	115
2003	1	22	436	93	436	15	80
	2	23	312	95	312	0	0

Key: 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.

(Figure 5 in Jones and Harding 1991) had peak frequencies in the 160 to 220 mm FL range, which is lower than we found on average during our study period (near 250 mm, Figure 7). Further, fewer fish over 320 mm FL were captured in these earlier studies than we did in most years. As abundance also increased substantially from estimates of about 1,200–1,500 fish ≥180 mm FL in 1988–1991 (Jones et al. 1989, 1990; Jones and Harding 1991) to the average level during this study period (about 2,000), it is clear the fishery rebounded rather quickly from the late 1980s to the mid-1990s. We do not know if abundance was once much higher than it is now, but we do believe very few trophy fish are present today despite the prohibition of legal harvest since 1991.

The potential adverse effect that size limits may have on genetic or heritable traits through long-term size selectivity was expressed during the development of the more conservative trout regulations adopted in 1994 (Harding and Jones 2005). Biologists have also been concerned about

Table 15.–Summary of goodness-of-fit tests for homogeneous capture/survival probabilities for the Jolly-Seber models used at Baranof Lake, 1994–2003. Overall chi-squares are the sum of the individual test statistics.

			Test 1[a]		Test 2[a]	
Year	Trips	Period	Chi-square	P-value	Chi-square	P-value
Annual model						
1994	1,2	1–2	–	–	–	–
1995	1–4	3–6	1.939	0.164	–	–
1996	1,2	7–8	11.301	0.001	0.212	0.899
1997	1,2	9–10	4.381	0.036	3.108	0.211
1998	1,2	11–12	0.127	0.721	6.357	0.042
1999	1,2	13–14	1.645	0.200	2.277	0.320
2000	1–3	15–17	1.552	0.213	2.715	0.257
2001	1–3	18–20	1.558	0.212	1.550	0.461
2002	1	21	2.566	0.109	4.720	0.094
2003	1,2	22–23	–	–	–	–
Overall χ^2: By test			25.1 (8 df)	0.002	20.9 (14 df)	0.103
Both tests			46.0 (22 df)	0.002		
Trip-by-trip model						
1994	1	1	–	–	–	–
	2	2	6.093	0.014	–	–
1995	1	3	2.511	0.113	4.742	0.093
	2	4	3.147	0.076	22.527	0.000
	3	5	4.904	0.027	12.495	0.002
	4	6	4.289	0.038	4.935	0.085
1996	1	7	9.613	0.002	3.115	0.211
	2	8	9.236	0.002	3.833	0.147
1997	1	9	6.971	0.008	7.847	0.020
	2	10	0.466	0.495	2.148	0.342
1998	1	11	0.135	0.714	5.697	0.058
	2	12	3.523	0.061	6.370	0.041
1999	1	13	1.653	0.199	3.736	0.155
	2	14	2.027	0.155	1.318	0.517
2000	1	15	2.082	0.149	7.762	0.021
	2	16	1.529	0.216	5.252	0.072
	3	17	9.562	0.002	2.791	0.248
2001	1	18	1.673	0.196	1.704	0.427
	2	19	2.432	0.119	16.608	0.000
	3	20	11.822	0.001	3.098	0.212
2002	1	21	2.566	0.109	0.243	0.886
2003	1	22	3.227	0.072	0.790	0.674
	2	23	–	–	–	–
Overall χ^2: By test			89.5 (21 df)	<0.001	117. (40 df)	<0.001
Both tests			206. (61 df)	<0.001		

[a] Test 1 is a 2 x 2 contingency table with 1 df; test 2 is 2 x 3 table with 2 df.

the growing number of observations that suggest the abundance of trophy-sized cutthroat trout has decreased in lakes that historically produced them. Jones (1981) reports on angler complaints about the lack of trophy fish in Virginia Lake and Hoffman and Marshall (1994) documented that few trophy fish were present in Wilson Lake. Bangs (2007) reports that trophy-sized cutthroat trout also seem to have largely disappeared from Patching Lake and further speculates that this may be attributed to significant harvests of large fish in the 1970s, 1980s, or earlier. As discussed by Bangs (2007), recent studies have shown that size-selective harvesting can influence the size composition of future generations of fish and that cessation of size-select harvest does not guarantee reverse selection back to the original state, or that the process could take many generations

Table 16.–Capture probabilities by tag-group and sampling trip for 2 goodness-of-fit tests based on Jolly-Seber models used at Baranof Lake, 1994–2003. See Table 15 for companion summary statistics.

		Chi-square test 1[a]		Chi-square test 2[b]		
Year	Trips	First captured before sample *i*	First captured in sample *i*	First captured before *i* –1, and not captured in *I* –1	First captured before *i* –1, and captured in *i* –1	First captured in *i* –1
Annual model						
1994	1,2	–	–	–	–	–
1995	1–4	0.152	0.182	–	–	–
1996	1,2	0.254	0.162	0.491	0.453	0.482
1997	1,2	0.230	0.173	0.520	0.592	0.605
1998	1,2	0.201	0.190	0.462	0.635	0.535
1999	1,2	0.262	0.223	0.517	0.432	0.555
2000	1–3	0.204	0.176	0.621	0.689	0.689
2001	1–3	0.105	0.086	0.802	0.867	0.825
2002	1	0.154	0.090	0.596	0.717	0.536
2003	1–2	–	–	–	–	–
Mean		0.195	0.160	0.573	0.626	0.604
Trip-by-trip model						
1994	1	–	–	–	–	–
	2	0.295	0.197	–	–	–
1995	1	0.377	0.312	0.373	0.455	0.298
	2	0.336	0.275	0.353	0.627	0.355
	3	0.295	0.211	0.301	0.375	0.182
	4	0.271	0.187	0.202	0.250	0.304
1996	1	0.309	0.198	0.313	0.417	0.253
	2	0.287	0.155	0.247	0.357	0.222
1997	1	0.325	0.222	0.318	0.512	0.235
	2	0.229	0.202	0.332	0.358	0.409
1998	1	0.282	0.265	0.245	0.400	0.333
	2	0.260	0.193	0.328	0.455	0.444
1999	1	0.358	0.296	0.212	0.267	0.304
	2	0.269	0.221	0.376	0.289	0.346
2000	1	0.351	0.290	0.243	0.250	0.360
	2	0.270	0.226	0.299	0.444	0.352
	3	0.282	0.174	0.331	0.370	0.261
2001	1	0.250	0.202	0.323	0.283	0.253
	2	0.196	0.154	0.439	0.610	0.653
	3	0.195	0.097	0.527	0.633	0.482
2002	1	0.135	0.090	0.589	0.605	0.553
2003	1	0.065	0.026	0.557	0.545	0.472
	2	–	–	–	–	–
Mean		0.268	0.200	0.345	0.427	0.354

[a] prob (recaptured again, given captured in event i) as function of stated first capture history.

[b] prob (captured in event i, given captured in events i or beyond) as function of stated first capture history.

(Conover and Munch 2002). Given the long period of high harvest rates in the late 1970s (twice our estimate of *MSY* at Turner Lake), a much longer period of time may be required before conditions for a trophy fishery similar to that of the past could occur. Certainly, these fisheries would be managed differently today (e.g., a low harvest quota for large fish or catch-and-release only fishing) if the goal was to maintain the trophy fisheries, particularly since the BOF recently adopted a policy for the management of sustainable wild trout fisheries (5 AAC 75.222), which states that wild trout, including cutthroat trout, should be managed in a manner to maintain genetic and phenotypic characteristics of the stock. While minimum size

Table 17.–Estimates of abundance (N), survival (ϕ), and births (B) of cutthroat trout ≥180 mm FL at Baranof Lake from the generalized (heterogeneity in survival) Jolly-Seber model. Estimates are from the computer program POPAN.

Year	Trips	Period	$\hat{N}$	$SE(\hat{N})$	$\hat{\phi}$	$SE(\hat{\varphi})$	$\hat{B}$	$SE(\hat{B})$
				Annual model				
1994	1,2	1–2	–	–	0.458[a]	n.a.[b]	n.a.	–
1995	1–4	3–6	7,963	884	0.435	0.048	1,968	557
1996	1,2	7–8	5,430	559	0.554	0.069	1,902	347
1997	1,2	9–10	4,911	529	0.604	0.088	3,930	648
1998	1,2	11–12	6,898	926	0.459	0.062	3,438	566
1999	1,2	13–14	6,603	728	0.556	0.061	2,894	506
2000	1–3	15–17	6,563	626	0.468	0.061	3,052	478
2001	1–3	18–20	6,124	729	0.337	0.067	1,323	377
2002	1	21	3,387	646	–	–	–	–
2003	1,2	22–23	–	–	–	–	–	–
				Trip-by-trip model				
1994	1	1	–	–	0.678	n.a.	n.a.	–
	2	2	8,406	1,319	0.482	0.060	1,991	832
1995	1	3	6,043	704	0.767	0.083	269	490
	2	4	4,901	474	0.856	0.112	1,678	470
	3	5	5,874	737	0.855	0.144	2,548	730
	4	6	7,569	1,174	0.651	0.106	913	533
1996	1	7	5,838	701	0.792	0.122	0[c]	405
	2	8	4,019	564	0.651	0.103	2,117	408
1997	1	9	4,731	578	0.931	0.147	36	411
	2	10	4,442	634	0.635	0.117	3,191	674
1998	1	11	6,012	965	0.776	0.131	567	540
	2	12	5,230	702	0.566	0.091	3,267	696
1999	1	13	6,229	928	0.920	0.137	1,147	710
	2	14	6,874	862	0.591	0.081	1,763	528
2000	1	15	5,824	714	0.935	0.130	750	549
	2	16	6,196	762	0.708	0.103	1,014	434
	3	17	5,399	667	0.787	0.127	2,075	556
2001	1	18	6,326	906	0.734	0.120	1,349	479
	2	19	5,994	763	0.534	0.084	148	276
	3	20	3,349	445	0.614	0.130	1,329	340
2002	1	21	3,387	646	0.843	0.345	2,570	1,112
2003	1	22	5,427	2,110	–	–	–	–
	2	23	–	–	–	–	–	–

[a] Survival or birth rate between event *i* and event + 1

[b] Value not estimated by the generalized JS model.

[c] Inadmissible estimate ($\phi > 1$ or B < 0) set to $\phi = 1$ or $B = 0$.

restrictions are frequently discussed, maximum size limits also offer advantages (Conover and Munch 2002). Future projects may be needed to evaluate the sport fishing regulations for trophy cutthroat trout to ensure that both the abundance and genetic characteristics of trophy populations are protected.

Surprises at Baranof Lake were similarly instructive. While Baranof Lake is much smaller than Turner Lake, it proved quite difficult to estimate abundance there, a humbling result in light of the great deal of prior work that seemed to provide good blueprints for conducting m-r studies for cutthroat trout in Southeast Alaska (e.g., Rosenkranz et al. 1999). We must conclude it is not so simple (see also Recommendations section below).

The large unsampled mid-lake area at Baranof Lake (>50 m) may be one reason for failures of several modeling assumptions (unequal capture

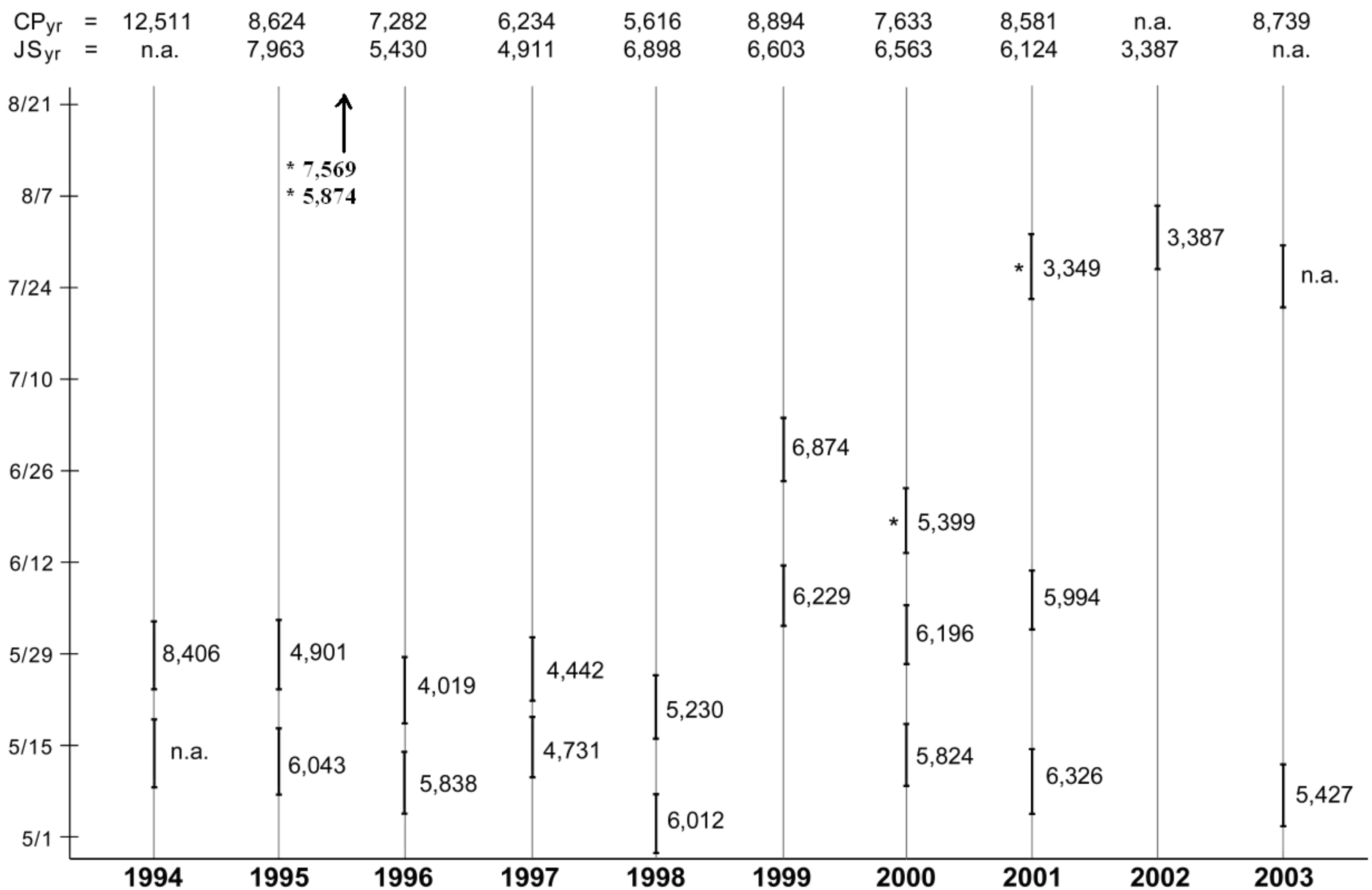

Figure 12.–Abundance estimates of cutthroat trout ≥180 mm FL at Baranof Lake under 3 experimental designs. The vertical bars over each year on the abscissa denote the span of individual sampling trips. Jolly-Seber (JS) estimates of abundance for each trip are shown just right of each bar. Annual JS estimates derived from pooling data from all sampling, and closed population (CP) estimates based on the first 2 sampling trips each year, are tabulated over each column. Note that the 1995 JS trip-by-trip estimates for two periods 8/23–8/30 (5,874) and 9/5–9/13 (7,569), are off-plot. Estimates for CP experiments were computed using data summaries compiled for the trip-by-trip JS analysis (trips marked with stars excluded), and thus may differ from those in previous analysis.

Table 18.–Estimates of survival for newly-captured and previously-captured cutthroat trout ≥180 mm FL at Baranof Lake. Estimates are from the computer program JOLLY.

Year	Trips	Period	$\hat{\phi}^{PrevCapt}$	SE($\hat{\phi}$)	$\hat{\phi}^{NewCapt}$	SE($\hat{\phi}$)
			Annual model			
1994	1,2	1–2	–	–	0.463	0.049
1995	1–4	3–6	0.384	0.059	0.461	0.045
1996	1,2	7–8	0.635	0.087	0.406	0.050
1997	1,2	9–10	0.677	0.108	0.509	0.071
1998	1,2	11–12	0.470	0.076	0.446	0.050
1999	1,2	13–14	0.606	0.083	0.517	0.050
2000	1–3	15–17	0.511	0.077	0.441	0.054
2001	1–3	18–20	0.384	0.086	0.314	0.060
2002	1	21	–	–	–	–
2003	1,2	22–23	–	–	–	–
			Trip-by-trip model			
1994	1	1	–	–	0.690	0.093
	2	2	0.618	0.105	0.412	0.043
1995	1	3	0.835	0.108	0.691	0.064
	2	4	0.915	0.128	0.747	0.093
	3	5	0.915	0.162	0.655	0.106
	4	6	0.687	0.119	0.475	0.067
1996	1	7	0.884	0.145	0.566	0.084
	2	8	0.687	0.113	0.370	0.069
1997	1	9	1.036	0.175	0.708	0.107
	2	10	0.651	0.126	0.577	0.100
1998	1	11	0.789	0.147	0.742	0.102
	2	12	0.615	0.107	0.456	0.067
1999	1	13	0.980	0.164	0.808	0.100
	2	14	0.630	0.097	0.516	0.062
2000	1	15	0.990	0.150	0.819	0.102
	2	16	0.738	0.115	0.618	0.082
	3	17	0.867	0.147	0.534	0.086
2001	1	18	0.769	0.135	0.621	0.089
	2	19	0.577	0.100	0.452	0.066
	3	20	0.714	0.158	0.355	0.083
2002	1	21	1.040	0.440	0.692	0.281
2003	1	22	–	–	–	–
	2	23	–	–	–	–

probabilities, etc.) that led us to prefer complex estimation models. The trip-by-trip JS estimates indicate significant recruitment and mortality between closely spaced trips in many years, which could indicate that fish move between sampled and unsampled areas (or become more or less available to sampling) between trips (Rosenkranz et al. 1999). Similarly, perhaps a component of the population was temporarily "unavailable" due to changes in behavior, diet, or other causes. In general, we also sampled earlier in the year than we did at Turner Lake, and water temperatures were lower than at Turner Lake. Our stream temperature data at Baranof Lake suggests fish may have been spawning during some sampling periods.

The deepwater areas in our studies are characterized by very low CPUE (if fished) and are thus routinely ignored. However, these areas are shallower and the bathymetry is more complex at Baranof Lake than it is at Turner Lake (Figures 2 and 3), so it is possible this large unsampled area provides useable fish habitat. As described by Rosenkranz et al. (1999), this situation can lead to some of the modeling problems we saw at Baranof Lake. The Baranof Lake analysis may also be unique because of the lack of interspecies

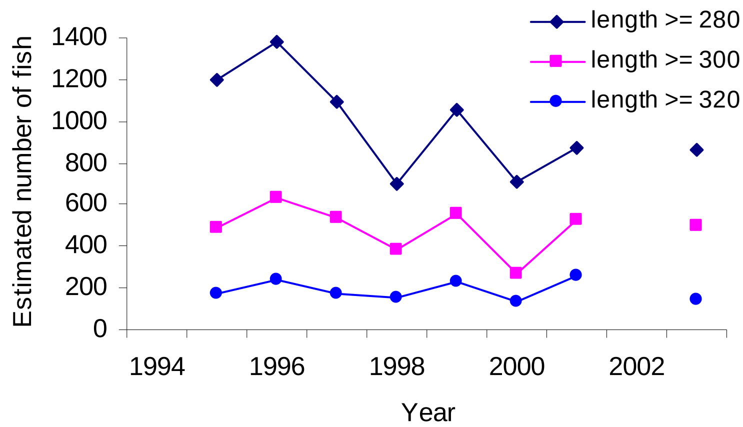

Figure 13.–Estimated number of cutthroat trout greater than 280 mm, 300 mm, and 320 mm FL in Baranof Lake, 1994–2003. A closed-population model estimate of abundance was not made for 2002.

competition with Dolly Varden, i.e., cutthroat trout may exist in habitat occupied in other lakes by Dolly Varden (cutthroat trout is the only fish species present in Baranof Lake).

Our sampling strategy at Baranof Lake attempted to avoid sampling during the spawning season, as some fish would, we assumed, be unavailable to our gear (see Rosenkranz et al. 1999). While this proved relatively easy at Turner Lake, it was not at Baranof Lake. Logistically, we could not download and analyze stream temperature data during our sampling trips to determine if sampling should proceed or not once we arrived. Behnke (1992) states that although spawning time varies by region, “temperatures of about 3 to 6°C may initiate spawning activity” and “actual spawning typically occurs when daily maximum water temperatures reach 6–9°C." Because annual environmental conditions could not be forecast, accurate planning to avoid specific stream temperatures associated with spawning was even more difficult. Once sampling schedules were developed for a sampling crew each year, they were not easy to change. Ripe female cutthroat trout were observed in our traps at Baranof Lake during April, May, June, July, and August over the years of this study. Taken with the water temperature data we recorded (Figure 11, Table 12), we conclude spawning activity occurred primarily during May and early June but could last well into July, and in some years begin before the lake was ice-free. Also, some margins of Baranof Lake are noticeably warmer than others, due to geothermal activity, and we observed activity in lake margins which appeared to be related to cutthroat trout spawning. Observations during the winter suggest that the lake outlet remains ice free through the winter and rearing cutthroat do utilize this area during the winter.

Abundance at Baranof Lake did appear stable at around 8,200 fish ≥180 mm FL over this study, and was thus likely near its current carrying capacity *K*. Warmer water and more protracted summers at Baranof Lake relative to the season at Turner Lake led to the lower annual survival rate (average 0.52) and an *MSY* estimate that is 19% of the population of fish ≥180 mm FL; this is 1.6 times the proportion of the population (12%) estimated for Turner Lake. Note that the average harvest rate of nearly 500 fish per year in the early 1990s (Appendix A5) is considerably less than our estimate of *MSY* for this system.

Aging cutthroat trout accurately by reading scales, especially for longer/older fish proved impossible. Research conducted by Ericksen (1997) after this study was initiated suggested aging cutthroat trout from Southeast Alaska was difficult, but possible. Ericksen reported that of the trout populations he studied (Turner, Baranof, and Florence), fish from Turner Lake had a high proportion of scales that formed the expected number of annuli. We thus

Table 19.–Parameters and calculations leading to estimates of MSY for cutthroat trout ≥180 mm FL at Baranof Lake. Average abundance over years ($\overline{N}$) is taken to be lake carrying capacity K. ADF&G Statewide Harvest Survey (SWHS) estimates of harvest are believed superior to the ADF&G cabin survey (Cabins) alternative. MSY for Baranof Lake is estimated at 1,575 fish ≥180 mm FL.

	N	*H*		$S =$	Z=-ln(S)	A = 1-exp(-Z)	$F = Z / A * H / N$	$M = Z - F$	*MSY*	$r = 1.2\ M$
Year	Best CP	Cabins harvest	SWHS harvest	Annual survival	Inst ann tot mort rate	Annual Mort rate	Inst ann (SWHS) harv mort rate	Inst ann nat mort rate	=0.3 **M** *K*; *K* = Ave CP	Inst rate of increase
1994	12,511	156	361							
1995	8,624	8	218	0.384	0.957	0.616	0.039	0.918	2,375	1.10
1996	7,282		144	0.635	0.454	0.365	0.025	0.430	938	0.52
1997	6,234		337	0.677	0.390	0.323	0.065	0.325	607	0.39
1998	5,616		223	0.470	0.755	0.530	0.057	0.698	1,177	0.84
1999	8,894	15	95	0.606	0.501	0.394	0.014	0.487	1,300	0.58
2000	7,633		159	0.511	0.671	0.489	0.029	0.643	1,472	0.77
2001	8,581		168	0.384	0.957	0.616	0.030	0.927	2,386	1.11
2002[a]		12	78							
2003	8,739		75							
Ave	8,235	48	186	0.524	0.669	0.476	0.037	0.632	1,465	0.76
F, *M*, *MSY*, and *r* based on averages of *N*, *H*, *Z*, *A* over years =							0.032	0.638	1,575	0.77

[a] A closed-population model estimate of abundance not made for 2002.

Figure 14.–Angler and harvest at the East Turner Lake U.S. Forest Service Shelter, in the late 1940s. The shelter still stands today. Each board measures 6 inches in height, indicating these fish range from about 18–26 inches (457 mm to 660 mm) in length. Photo courtesy of Richard Bloomquist.

hoped that the inherent problems related to low precision and bias (under-aging older fish) could be ameliorated in this study by employing a well-trained scale reader. However, high imprecision and bias in our estimates of age made the calculation of admissible (sensical) unbiased age composition vectors impossible (see Campana 2001). We have no easy cure for this problem; contemplating future large-scale aging projects like this one seem especially ominous. Our only suggestion is to put even greater emphasis on training and careful analysis of each scale to be read, as suggested by Ericksen (1997). This makes aging cutthroat trout a very costly proposition at best.

Behnke (2002) states that most fluvial and resident lake forms of coastal cutthroat trout attain a maximum age of 10 years, except in the coldest lakes where the long periods of low temperatures can result in a lower metabolic rate. The longevity of resident coastal cutthroat trout in Alaska was previously reported to range up to 12 years, using scale/otolith patterns to approximate age (Jones et al. 1989). Results from m-r studies at 3 Alaskan lakes during the last several years suggest that non-anadromous coastal cutthroat trout in Alaska attain ages of 15 to 18 years. A 557 mm FL cutthroat trout at Turner Lake was captured during our sampling on June 27, 2002 using hook-and-line gear. This fish had previously been tagged with a uniquely numbered anchor T-bar tag by us on July 11, 1990 when it was 164 mm in fork length and an estimated 3 years of age (based on the scale pattern). This fish thus reached 15 years of age (3 plus the 12 year hiatus) and had not been recaptured during our annual samplings prior to its recapture in 2002. The ADF&G employees who captured this fish noted a sore around the anchor T-bar tag but otherwise it appeared healthy. Another tagged cutthroat trout was brought into our Sitka office after being harvested by an angler at Baranof Lake in August 2008. One of our colleagues (Dave Magnus) measured the fish at 329 mm fork length, and collected the anchor T-bar tag, scales, and otoliths. This fish was tagged by us on May 14, 1995, when it was 240 mm in fork length and an estimated 5 years of age (based on the scale pattern). Thus, we estimate its age in 2008 at 18 years. Another angler returned to us a tag from a cutthroat trout caught at Florence Lake on October 3, 2004. This fish was captured by us in a large trap and marked on May 10, 1993 when it was 229 mm in fork length and an estimated 6 years of age (based on the scale pattern). The fish was not recaptured in subsequent studies in 1996, 1997, 2002, or 2003. We thus estimate its age in 2004 at 17 years. The angler reported to us the fish was about 18 inches long at capture, so it apparently grew just over 8 inches in 12 summers at large.

RECOMMENDATIONS

Years of experience teach us that m-r studies on potamodromous lake dwelling cutthroat trout populations are not affairs to be taken lightly. Studies begin by carefully deciding which population parameters are essential to estimate and the precision levels that are required. We find the "Robust Design" recommended by Pollock et al. (1990), a combination of CP and JS models, to be valuable for investigating trout populations. Pollock et al. (1990, p.76) describes a minimal robust design consisting of 3 primary sampling periods (years) and 5 secondary periods within each year. In large, remote lakes like Turner and Baranof we think that 2 or 3 secondary periods within a year mark a practical upper limit to both sampling effort and the expectation to sample from a closed, homogeneous population. Sampling large lakes more frequently would require heavy investments in manpower and sampling equipment. Limiting sampling to the minimum number of secondary (or primary) periods does however limit ones ability to detect heterogeneity in capture probabilities and evaluate model assumptions. Simulations, like those available in POPAN, help quantify expected precision in a successful J-S experiment and are thus not to be avoided. Researchers should complete a draft analysis using all available data after each sampling year is complete, in order to efficiently respond to unforeseen findings, evaluate assumptions, and craft the best final research product.

Selecting when, where, and how to sample is also no small task. In Turner and Baranof lakes, different gear types were required to obtain adequate, representative samples, a fact we learned during early studies at each lake. For example, baited-trap and hook-and-line sampling were practically ineffective at both lakes at certain times of the year. Much previous work (e.g., Rosenkranz et al. 1999) has taught us the importance of proportionally sampling all habited areas in a lake, and we gravitated to sampling from the entire surface daily, rather than moving from area to area each day. We note it is difficult to determine, *a priori* at least, when large, deep mid-lake areas might contain small (but significant) proportions of a population that either must be sampled to avoid experimental difficulties and biases, or be considered into the experimental design (say through mixing). Preliminary work with sonar, gillnets, hoop traps, or even angler surveys might be used to evaluate fish presence or absence as a function of depth. Where fish are present in deep areas, passive gear types may be hard to set (anchor on ground) and any gear will likely have a very low CPUE. Experimenters should be prepared, especially when working on large lakes, to utilize knowledge from initial sampling to craft effective sampling techniques.

Sampling trips should be conducted at similar times each year because recruitment and death, and thus population size, have definite seasonal patterns. When to sample may be determined by environmental conditions (e.g., avoiding ice, high summer water temperatures), fishing success (e.g., Figure 4), and an attempt to avoid spawning periods when fish are unavailable for capture. Placing temperature recorders in likely spawning streams is an easy way to determine when temperatures are best for spawning. Installation of an immigrant/emigrant weir on a small spawning stream can help correlate temperature with spawn timing, and provide data on the number and size of spawning fish. Studies at Florence Lake suggest the length of time a cutthroat trout may spend in a small spawning stream can vary from 2 to 21 days (Harding and Jones 1993).

In lakes with inlet streams where water temperatures reach adequate spawning requirements at widely varying times, it may be difficult to avoid sampling during some spawning activity and thus encountering some experimental bias. If annual estimates of abundance are paramount, placing one other sampling event during a non-spawning period leads to an unbiased CP estimate. If overwinter survival estimates are needed, the first event of the J-S experiment should obviously not occur during a spawning period. Because environmental conditions (ice out, stream temperatures, etc) are hard to accurately forecast, we like a design that places the first sampling trip each year after spawning is thought to be largely concluded. Ideally, a short break would occur to allow for mixing, then (at least) one additional trip is made prior to the development of warm summer water temperatures. As water temperatures rise, a small fraction of the fish tagged each day or period can be held overnight to evaluate short-term tagging stress and mortality.

MSY is a quantity that provides: 1) a description of the facts of life regarding fish stocks in relation to exploitation; 2) a clearly definable objective of management; and 3) a measure of the success with which the stock is being managed (Gulland 1983). As harvest guidelines set at estimated *MSY* are likely to be high (Larkin 1977; Gulland 1983), our estimates of *MSY* serve as a "preliminary reference benchmark" (Garcia et al. 1989) and an estimate of the upper limit of acceptable harvest for these 2 lakes. Such a management scheme for cutthroat trout suggests annual harvests be monitored with good accuracy and precision, and periodic monitoring of abundance occur should harvests (or estimated mortality) approach *MSY* levels. Such intensive management might someday be appropriate at Baranof Lake, but Turner Lake should, we believe, be managed as it currently is, for catch-and-release.

While current angling regulations at Turner Lake do not permit angler harvest, the number of fish annually caught and released average about 43% (= 875/2,047) of the estimated average abundance during this experiment (i.e., average of cabin survey estimates in 1994, 1995, 1999, 2002 and SWHS 1996–1998, 2000–2001 and 2003; Appendix A5, Table 9). The number of cutthroat caught and released at Baranof Lake is typically 21% (= 1,726/8,235) of the estimated annual abundance (i.e., average SWHS total catch and harvest, 1994–2003; Appendix A5, Table 19).

A review of the literature on catch-and-release suggests that the discard mortality of cutthroat trout caught using non-baited lures, flies and spinners typically ranges from 1.8% to 6.7%, but may be as high as 24% for anadromous and resident trout species (Taylor and White 1992; Wright 1992; and Pauley and Thomas 1993). We thus recognize that catch-and-release mortality may not be insignificant in these systems (most especially at Turner Lake) and should be factored into any future harvest-based management at these systems.

High incidental mortality rates may also impact management based on catch-and-release or minimum length regulations. Coggins et al. (2007) shows, for example, how incidental mortality rates as low as 5% for long-lived low productivity species may lengthen the time necessary for a population to rebound.

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APPENDIX A

Appendix A1.–History of finclips, dye marks, and tags used at Turner Lake, 1994 through 2003.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Clips										
Adipose fin	Yes			Yes	Yes	Yes	Yes	Yes	Yes	Yes
Left ventral fin		Yes								
Right ventral fin			Yes							
Left axillary fin					Yes					
Right axillary fin				Yes		Yes				
Blue dye mark										
Anal fin						Yes				
Left ventral fin							Yes			
Right ventral fin										
Red dye mark										
Anal fin								Yes		
Right ventral fin									Yes	
Left ventral fin										Yes
Visual Implant Tag										
Clear tissue over eye	Yes	Yes	Yes	Yes	Yes					
Anchor T-bar or PIT tag										
See text for location	T-bar	T-bar	T-bar	PIT	PIT	PIT	PIT	PIT	PIT	PIT

Appendix A2.–History of finclips, dye marks, and other marks used as secondary marks at Baranof Lake, 1994 through 2003. Anchor T-bar tags were used as primary marks each year.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Clips										
Adipose fin	Yes		Yes				Yes		Yes	
Left ventral fin		Yes[a]		Yes						
Right ventral fin		Yes[b]								
Left axillary fin						Yes				
Right axillary fin					Yes			Yes		
Blue dye mark										
Anal fin					Yes					
Left ventral fin						Yes				
Right ventral fin							Yes			
Red dye mark										
Anal fin								Yes		
Left ventral fin									Yes	
Right ventral fin										Yes

[a] Applied during trips 1 & 2.

[b] Applied during trips 3 & 4.

Appendix A3.–Catch of cutthroat trout (CT) and Dolly Varden (DV) at Turner Lake by year, 1994–2003.

	CT		
Year	≥180 mm	< 180 mm	DV
1994	1,143	407	2,788
1995	480	62	1,134
1996	376	95	1,881
1997	849	137	492
1998	395	159	864
1999	332	62	822
2000	511	52	870
2001	510	61	549
2002	470	117	727
2003	678	218	792
Total	5,744	1,370	10,919

Appendix A4.–Catch-per-unit-effort (CPUE) of cutthroat trout ≥180 mm FL with large traps (LT) and hook-and-line (HL) at Turner Lake, 1994–2003. See Table 1 for dates of the 23 sample periods.

			CPUE	
Year	Trip	Period	LT[a] (per trap)	HL (per rod hr)
1994	1	1	1.31	3.3
	2	2	1.59	3.6
	3	3	1.08	2.3
	4	4	0.76	1.9
1995	1	5	0.39	4.9
	2	6	0.30	3.1
1996	1	7	0.57	0.3
	2	8	0.31	1.1
	3	9	0.33	2.6
1997	1	10	0.51	4.9
	2	11	0.49	4.4
1998	1	12	0.35	3.5
	2	13	0.34	2.3
1999	1	14	0.43	2.8
	2	15	0.57	2.5
2000	1	16	0.71	3.5
	2	17	0.72	3.7
2001	1	18	0.86	2.8
	2	19	0.77	3.9
2002	1	20	1.10	2.1
	2	21	0.81	3.5
2003	1	22	1.18	4.0
	2	23	1.32	4.0

[a] Overnight sets (average soak about 22 hrs/trap).

Appendix A5.–Estimates of sport fishing effort, harvest and catch of cutthroat trout at Turner and Baranof lakes, 1990 to 2003. Fishery statistics are from Alaska Department of Fish and Game (ADF&G) postal surveys of: A) users of the U. S. Forest Service (USFS) recreational cabins at each lake, and B) survey of persons who purchased Alaska sport fishing licenses in the survey year (SWHS)[a].

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
TURNER LAKE														
Survey of USFS Cabin Users														
Hours fished			912	1,373	1,798	1,622				943			511	
Days fished			241	379	425	348				199			216	
Harvest			24	63	88	57				58			251	
Released			288	911	860	754				739			901	
Catch (harvest+release)			312	974	948	811				797			1,152	
Statewide Harvest Survey (SWHS)														
No. anglers	69	98	224	131	130	237	297	330	294	63	97	115	33	100
Days fished	91	251	586	182	319	678	597	900	359	90	295	220	33	163
Harvest	327	123	0	0	53	0	0	0	0	0	0	0	0	0
Catch (harvest+release)	327	167	376	323	294	957	1,704	902	859		753	878	0	93
BARANOF LAKE														
Survey of USFS Cabin Users														
Hours fished			528	199	537	49				69			44	
Days fished			113	53	126	17				20			11	
Harvest			312	161	156	8				15			12	
Released			1,488	339	841	81				89			51	
Catch (harvest+release)			1,800	500	997	89				104			63	
Statewide Harvest Survey (SWHS)														
No. anglers	426	319	399	362	321	451	234	671	513	320	369	321	300	144
Days fished	617	497	608	842	693	1,109	364	1,111	702	498	750	683	576	187
Harvest	426	392	422	841	361	218	144	337	223	95	159	168	78	75
Catch (harvest+release)	1,413	654	1,952	2,943	4,304	1,940	2,192	2,910	2,888	1,020	1,476	773	1,371	253

[a] Surveys of USFS cabin users only made in 6 years shown.

Appendix A6.–Estimated length composition (mm FL) of cutthroat trout ≥180 mm FL, Turner Lake.

	Proportion by length category[a]									
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–199	0.131	0.064	0.119	0.080	0.092	0.078	0.146	0.069	0.110	0.182	0.107
200–219	0.161	0.148	0.094	0.123	0.098	0.104	0.097	0.089	0.102	0.169	0.119
220–239	0.153	0.139	0.151	0.149	0.135	0.117	0.089	0.103	0.121	0.131	0.129
240–259	0.168	0.139	0.182	0.141	0.132	0.130	0.136	0.125	0.108	0.110	0.137
260–279	0.149	0.121	0.126	0.147	0.153	0.156	0.123	0.145	0.100	0.084	0.131
280–299	0.097	0.087	0.094	0.130	0.153	0.104	0.109	0.125	0.106	0.083	0.109
300–319	0.053	0.112	0.075	0.086	0.111	0.121	0.117	0.135	0.091	0.068	0.097
320–339	0.039	0.073	0.101	0.055	0.069	0.091	0.071	0.071	0.081	0.062	0.071
340–359	0.017	0.034	0.025	0.028	0.021	0.059	0.034	0.073	0.085	0.037	0.041
360–379	0.019	0.023	0.006	0.029	0.018	0.016	0.034	0.048	0.036	0.038	0.027
380–399	0.003	0.030	0.006	0.011	0.008	0.003	0.022	0.008	0.025	0.019	0.014
400–419	0.002	0.009	0.019	0.008	0.000	0.003	0.008	0.002	0.008	0.006	0.006
420–439	0.003	0.005	0.000	0.006	0.000	0.003	0.006	0.000	0.013	0.005	0.004
440–459	0.002	0.011	0.000	0.003	0.000	0.010	0.004	0.004	0.006	0.003	0.004
460–479	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.002	0.001
480–499	0.002	0.005	0.000	0.000	0.000	0.003	0.002	0.004	0.002	0.000	0.002
>500	0.000	0.000	0.000	0.003	0.003	0.000	0.000	0.000	0.002	0.000	0.001
	SE (proportion by length category)										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–199	0.014	0.012	0.026	0.010	0.015	0.015	0.016	0.011	0.014	0.015	0.038
200–219	0.015	0.017	0.023	0.012	0.015	0.017	0.013	0.013	0.013	0.015	0.030
220–239	0.015	0.017	0.028	0.013	0.018	0.018	0.013	0.014	0.014	0.013	0.021
240–259	0.015	0.017	0.031	0.012	0.017	0.019	0.015	0.015	0.013	0.012	0.023
260–279	0.015	0.016	0.026	0.013	0.019	0.021	0.015	0.016	0.013	0.011	0.024
280–299	0.012	0.013	0.023	0.012	0.019	0.017	0.014	0.015	0.013	0.011	0.022
300–319	0.009	0.015	0.021	0.010	0.016	0.019	0.014	0.015	0.013	0.010	0.026
320–339	0.008	0.012	0.024	0.008	0.013	0.016	0.012	0.012	0.012	0.010	0.018
340–359	0.005	0.009	0.012	0.006	0.007	0.013	0.008	0.012	0.012	0.008	0.023
360–379	0.006	0.007	0.006	0.006	0.007	0.007	0.008	0.010	0.008	0.00	0.013
380–399	0.002	0.008	0.006	0.004	0.005	0.003	0.007	0.004	0.007	0.005	0.010
400–419	0.002	0.005	0.011	0.003	0.000	0.003	0.004	0.002	0.004	0.003	0.005
420–439	0.002	0.003	0.000	0.003	0.000	0.003	0.003	0.000	0.005	0.003	0.004
440–459	0.002	0.005	0.000	0.002	0.000	0.006	0.003	0.003	0.003	0.002	0.004
460–479	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.002	0.002
480–499	0.002	0.003	0.000	0.000	0.000	0.003	0.002	0.003	0.002	0.000	0.002
>500	0.000	0.000	0.000	0.002	0.003	0.000	0.000	0.000	0.002	0.000	0.001

[a] See Table 1 for dates that length samples were collected.

Appendix A7.–Estimated age composition of cutthroat trout ≥180 mm FL at Turner Lake, 1994–2003.

	Proportion by age category[a]										
Age (years)	1994[b]	1995	1996	1997	1998	1999	2000	2001	2002[b]	2003[b]	Ave
2		0.028	0.000	0.018	0.041	0.025	0.000	0.000			0.016
3		0.300	0.201	0.254	0.263	0.240	0.234	0.140			0.233
4		0.249	0.381	0.304	0.278	0.254	0.309	0.417			0.313
5		0.202	0.154	0.232	0.229	0.233	0.194	0.230			0.211
6		0.162	0.135	0.127	0.117	0.159	0.144	0.122			0.138
7		0.036	0.107	0.047	0.049	0.067	0.072	0.072			0.064
8		0.020	0.016	0.018	0.015	0.014	0.040	0.014			0.020
9		0.004	0.006	0.000	0.008	0.007	0.007	0.004			0.005
	SE (proportion by age category)										
Age (years)	1994[b]	1995	1996	1997	1998	1999	2000	2001	2002[b]	2003[b]	Ave
2		0.010	0.000	0.008	0.012	0.009	0.000	0.000			0.016
3		0.029	0.023	0.026	0.027	0.025	0.025	0.021			0.051
4		0.027	0.027	0.028	0.028	0.026	0.028	0.030			0.064
5		0.025	0.020	0.025	0.026	0.025	0.024	0.025			0.030
6		0.023	0.019	0.020	0.020	0.022	0.021	0.020			0.018
7		0.012	0.017	0.013	0.013	0.015	0.016	0.016			0.023
8		0.009	0.007	0.008	0.007	0.007	0.012	0.007			0.009
9		0.004	0.004	0.000	0.005	0.005	0.005	0.004			0.003

[a] See Table 1 for dates that age samples were collected.

[b] Scales not read for age in these years.

Appendix A8.–Estimated numbers of cutthroat trout ≥180 mm FL by length, Turner Lake at Turner Lake, 1994–2003.

	Number by length category										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–220	584	411	472	374	331	293	453	562	393	640	462
220–260	642	540	736	532	464	398	419	814	425	439	544
260–300	492	403	486	509	533	419	434	966	382	305	490
300–340	183	358	389	259	313	341	351	735	319	238	344
340–380	71	111	69	105	69	121	128	432	225	137	139
380–420	10	75	56	35	14	10	57	36	60	47	41
420–460	10	31	0	16	0	21	19	14	35	15	17
460–500	3	9	0	0	9	5	4	14	4	3	5
>500	7	4	0	7	9	0	0	0	14	3	5
Sum	2,003	1,942	2,207	1,838	1,743	1,609	1,866	3,575	1,856	1,826	2,047
	SE (number by length category)										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–220	83	81	129	47	72	84	76	136	63	79	122
220–260	90	102	187	64	96	111	71	191	67	58	92
260–300	72	79	132	61	109	116	73	223	62	43	94
300–340	33	72	110	36	68	96	61	173	53	36	81
340–380	18	29	34	19	22	39	28	108	40	24	66
380–420	6	22	30	10	8	8	17	18	16	13	25
420–460	6	13	0	6	0	11	9	10	12	7	13
460–500	3	6	0	0	7	5	4	10	4	3	4
>500	5	4	0	4	7	0	0	0	7	3	5

Appendix A9.–Catch of cutthroat trout (CT) and Dolly Varden (DV) at Baranof Lake by year.

	CT		
Year	≥180 mm	< 180 mm	DV
1994	2,450	658	0
1995	3,105	546	0
1996	1,119	218	0
1997	1,180	154	0
1998	1,345	297	0
1999	1,611	351	0
2000	2,112	484	0
2001	2,286	425	0
2002	593	152	0
2003	781	121	0
Total	16,582	3,406	0

Appendix A10.–Catch-per-unit-effort (CPUE) of cutthroat trout ≥180 mm FL with large traps (LT) and hook-and-line (HL) at Baranof Lake.

			CPUE	
Year	Trip	Period	LT[a] (per trap)	HL (per rod hr)
1994	1	1	9.6	ND[b]
	2	2	8.7	1.2
1995	1	3	6.84	0.4
	2	4	5.48	0.8
	3	5	3.96	3.5
	4	6	3.45	4.2
1996	1	7	5.50	0.1
	2	8	2.58	0.0
1997	1	9	3.71	ND[b]
	2	10	2.80	0.7
1998	1	11	3.07	0.2
	2	12	3.78	0.5
1999	1	13	3.69	0.0
	2	14	5.26	0.0
2000	1	15	4.00	ND[b]
	2	16	4.10	0.0
	3[c]	17	3.96	3.4
2001	1	18	3.66	ND[b]
	2	19	5.56	0.1
	3[c]	20	3.77	2.0
2002	1	21	4.16	1.2
2003	1	22	2.49	ND[b]
	2	23	1.64	3.7

[a] Overnight sets (average soak about 22 hrs/trap).

[b] No hook-and-line during trip.

[c] Not used in trip-by-trip JS analysis.

Appendix A11.–Length composition (mm FL) of cutthroat trout ≥180 mm FL, Baranof Lake.

	Proportion by length category [a]										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–199	0.236	0.203	0.186	0.163	0.233	0.233	0.274	0.253	0.156	0.209	0.215
200–219	0.201	0.217	0.174	0.218	0.230	0.243	0.250	0.271	0.215	0.227	0.225
220–239	0.156	0.205	0.177	0.183	0.195	0.178	0.172	0.185	0.229	0.195	0.188
240–259	0.120	0.144	0.142	0.144	0.130	0.135	0.120	0.119	0.161	0.167	0.138
260–279	0.100	0.092	0.129	0.116	0.087	0.091	0.092	0.070	0.074	0.103	0.096
280–299	0.083	0.081	0.103	0.091	0.056	0.056	0.057	0.040	0.030	0.041	0.064
300–319	0.072	0.037	0.054	0.058	0.042	0.036	0.018	0.032	0.034	0.041	0.042
320–339	0.021	0.015	0.025	0.022	0.025	0.019	0.012	0.021	0.060	0.009	0.023
340–359	0.006	0.003	0.006	0.006	0.002	0.006	0.003	0.007	0.025	0.000	0.006
360–379	0.003	0.001	0.001	0.000	0.000	0.002	0.001	0.001	0.011	0.007	0.003
380–399	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.005	0.000	0.001
>400	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	SE (proportion by length category)										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–199	0.009	0.009	0.012	0.011	0.012	0.011	0.012	0.011	0.015	0.019	0.038
200–219	0.008	0.010	0.012	0.012	0.012	0.011	0.011	0.011	0.017	0.020	0.027
220–239	0.007	0.009	0.012	0.011	0.011	0.010	0.010	0.010	0.018	0.019	0.020
240–259	0.007	0.008	0.011	0.010	0.009	0.009	0.009	0.008	0.016	0.018	0.017
260–279	0.006	0.007	0.010	0.009	0.008	0.007	0.008	0.006	0.011	0.015	0.018
280–299	0.006	0.006	0.009	0.008	0.006	0.006	0.006	0.005	0.007	0.010	0.024
300–319	0.005	0.004	0.007	0.007	0.006	0.005	0.004	0.004	0.008	0.010	0.015
320–339	0.003	0.003	0.005	0.004	0.004	0.003	0.003	0.004	0.010	0.005	0.014
340–359	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.007	0.000	0.007
360–379	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.004	0.004	0.003
380–399	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.003	0.000	0.002
>400	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[a] See Table 1 for dates that length samples were collected.

Appendix A12.–Age composition of cutthroat trout ≥180 mm FL, Baranof Lake.

	Proportion by age category[a]									
Age (years)	1994	1995[b]	1996[b]	1997[b]	1998	1999[b]	2000[b]	2001[b]	2002[b]	2003	Ave
2	0.007				0.000					0.007	0.005
3	0.162				0.158					0.137	0.152
4	0.412				0.424					0.356	0.398
5	0.324				0.259					0.349	0.311
6	0.074				0.108					0.130	0.104
7	0.020				0.043					0.014	0.026
8	0.000				0.007					0.007	0.005
	SE (proportion by age category)										
Age (years)	1994	1995[b]	1996[b]	1997[b]	1998	1999[b]	2000[b]	2001[b]	2002[b]	2003	Ave
2	0.007				0.000					0.007	0.004
3	0.030				0.031					0.029	0.014
4	0.041				0.042					0.040	0.036
5	0.039				0.037					0.040	0.047
6	0.022				0.026					0.028	0.028
7	0.012				0.017					0.010	0.015
8	0.000				0.007					0.007	0.004

[a] See Table 1 for dates that age samples were collected.

[b] Scales not read for age in these years.

Appendix A13.–Estimated numbers of cutthroat trout ≥180 mm FL at length, Baranof Lake.

	Number by length category										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002[a]	2003	Ave
180–199	2,952	1,751	1,357	1,017	1,306	2,074	2,089	2,169		1,824	1,767
200–219	2,520	1,873	1,271	1,361	1,293	2,165	1,907	2,327		1,984	1,851
220–239	1,952	1,770	1,291	1,140	1,094	1,586	1,314	1,590		1,704	1,544
240–259	1,499	1,241	1,036	898	729	1,199	913	1,021		1,463	1,138
260–279	1,255	796	943	721	490	813	705	600		902	788
280–299	1,041	702	749	565	317	500	433	342		361	526
300–319	906	318	395	360	234	324	139	274		361	350
320–339	266	131	181	134	139	165	91	184		80	188
340–359	78	23	47	38	9	51	27	63		0	53
360–379	36	9	7	0	0	17	11	5		60	22
380–399	5	5	7	0	4	0	5	5		0	8
>400	0	5	0	0	0	0	0	0		0	0
Sum	12,511	8,624	7,282	6,234	5,616	8,894	7,633	8,581		8,739	8,235
	SE (number by length category)										
Length, (mm FL)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Ave
180–199	272	269	289	187	149	248	346	338		455	344
200–219	236	287	271	245	147	258	317	362		491	265
220–239	189	272	275	208	127	195	223	252		427	205
240–259	151	195	224	167	91	153	160	168		372	167
260–279	131	130	205	137	67	111	127	105		243	159
280–299	113	117	166	110	48	76	83	66		117	204
300–319	101	60	94	75	39	55	35	55		117	129
320–339	43	31	50	35	28	35	26	41		43	117
340–359	21	11	20	15	6	18	13	20		0	57
360–379	14	7	7	0	0	10	8	5		36	28
380–399	5	5	7	0	4	0	5	5		0	13
>400	0	5	0	0	0	0	0	0		0	1

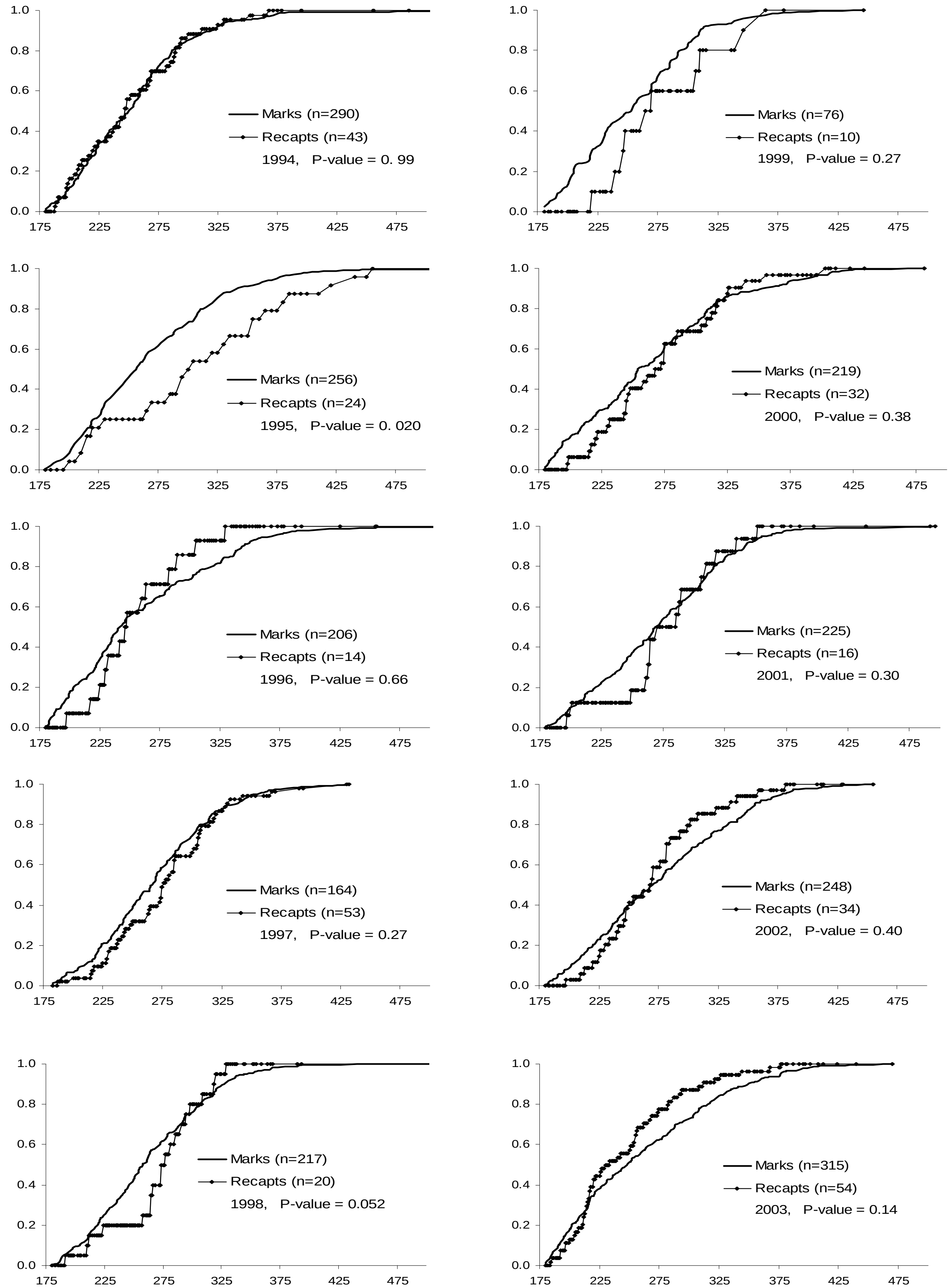
[a] A closed-population model estimate of abundance not made for 2002.

Appendix A14.–Computer files used in the analysis and completion of this report and archived in Douglas Regional office and at RTS in Anchorage.

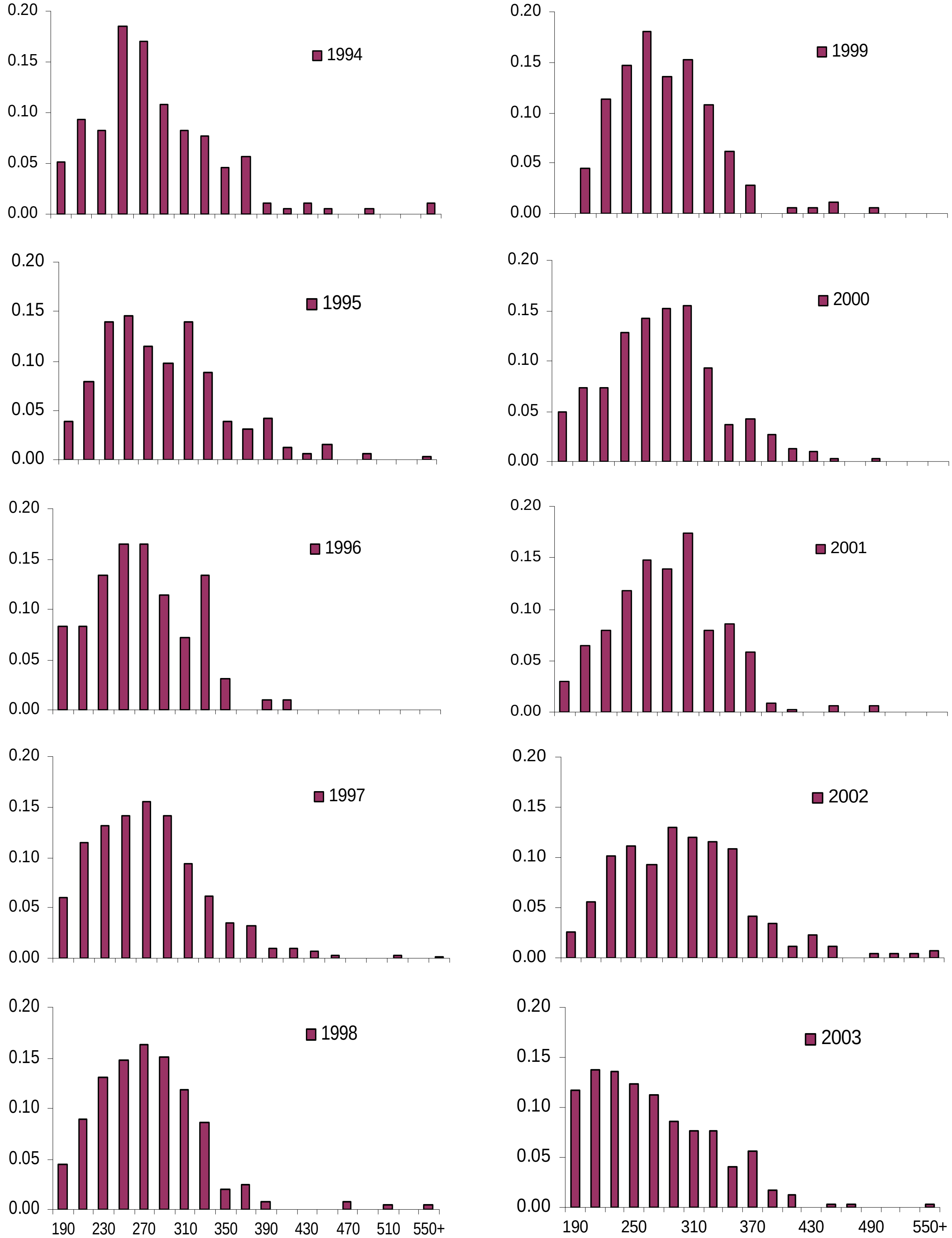
File Name	Description
Baranof Length and Age Comp#2.XLS	Length/age composition worksheet for Baranof Lake
Baranof *MSY*#2.xls	*MSY* worksheet for Baranof Lake
Baranof_Capture_History_93_04.XLS	All data utilized in abundance estimation at Baranof Lake including mark–recapture history
Baranof_FDS_Temp.XLS	Temperature data for Baranof Lake
BL_9403.RAW	Popan data file of raw capture history for Baranof Lake
Bl_all03.POP	Popan program file used to generate abundance estimate for Baranof Lake
BL_ALL03.RES	POPAN output with abundance estimates for Baranof Lake
BaranofEffort.xls	Catch, effort, and CPUE data at Baranof Lake
Baranof KS Len All.xls	Length data and analysis of fish captured at Baranof Lake
Turner Length and Age Comp#2.XLS	Length/age composition worksheet for Turner Lake
Turner *MSY*#2.xls	*MSY* worksheet for Turner Lake
Turner_Capture_History_93_04.XLS	All data utilized in abundance estimation at Turner Lake including mark–recapture history
Turner_FDS_Temp.XLS	Temperature data for Turner Lake
TL9403.RAW	Popan data file of raw capture history for Turner Lake
TL9403.POP	Popan program file used to generate abundance estimate for Turner Lake
TL9403.RES	POPAN output with abundance estimates for Turner Lake
Turner KS Len All.xls	Length data and analysis of fish captured at Turner Lake
TurnerEffort.xls	Catch, effort, and CPUE data at Turner Lake

APPENDIX B

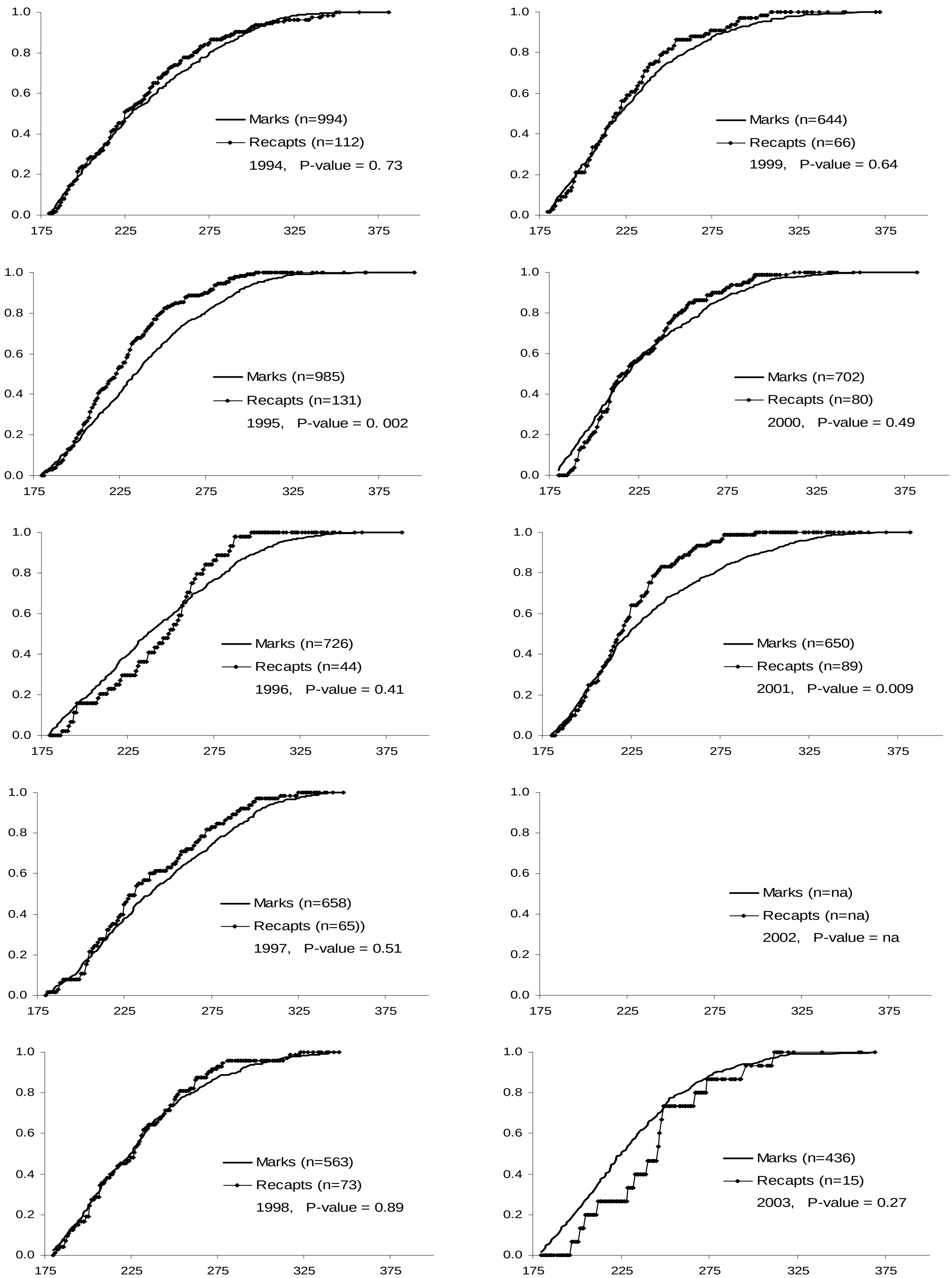
Appendix B1.–Cumulative fraction of fork lengths (mm) of cutthroat trout marked versus fork lengths recaptured, Turner Lake, 1994–2003.



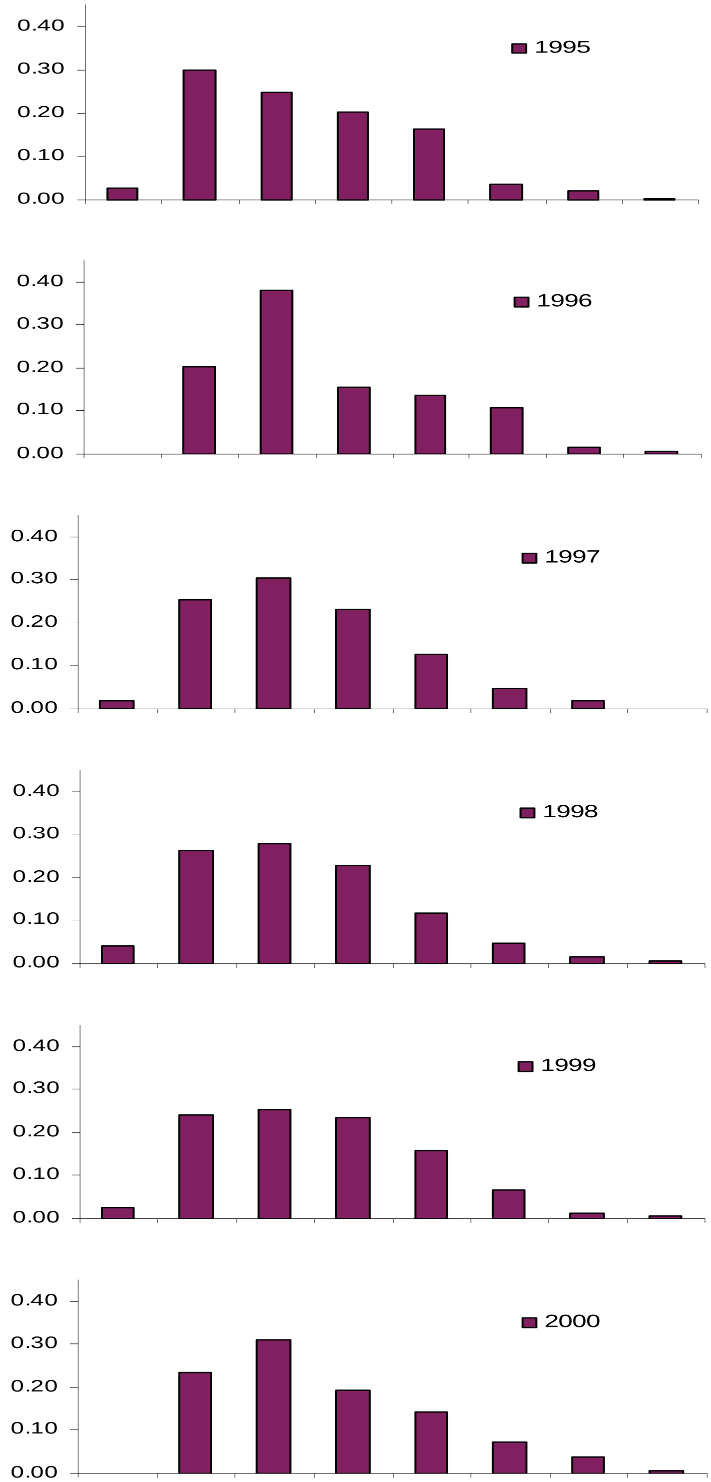
Appendix B2.–Estimated length composition (y axis = percent frequency) at Turner Lake, 1994–2003. Lengths (x axis) are the mid-point of 20 mm FL intervals beginning at 180 mm (180 to <200 mm, 200 to <220 mm, etc).



Appendix B3.–Estimated length composition (y axis = percent frequency) of Turner Lake catch by hook-and-line. Lengths (x axis) are the mid-point of 20 mm FL intervals beginning at 180 mm (180 to <200 mm, 200 to <220 mm, etc).



Appendix B4.–Estimated age (x axis) and percent composition (y axis) at Turner Lake, 1995–2001.



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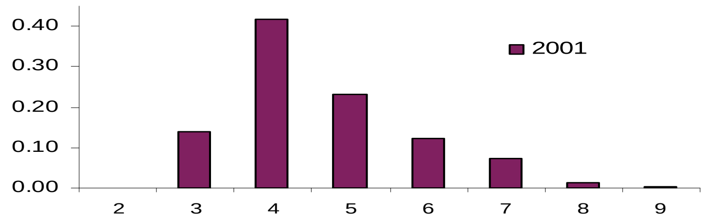
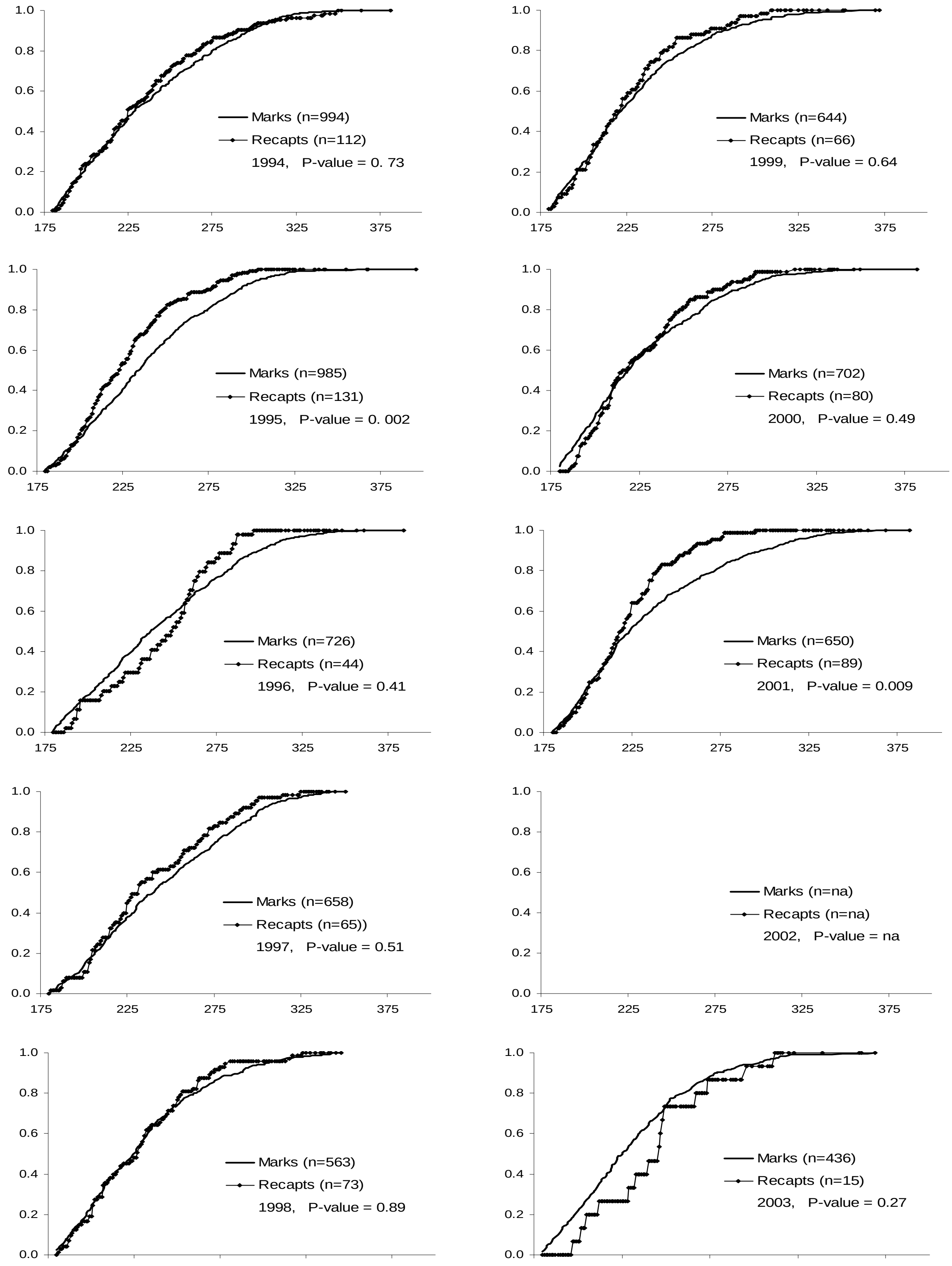
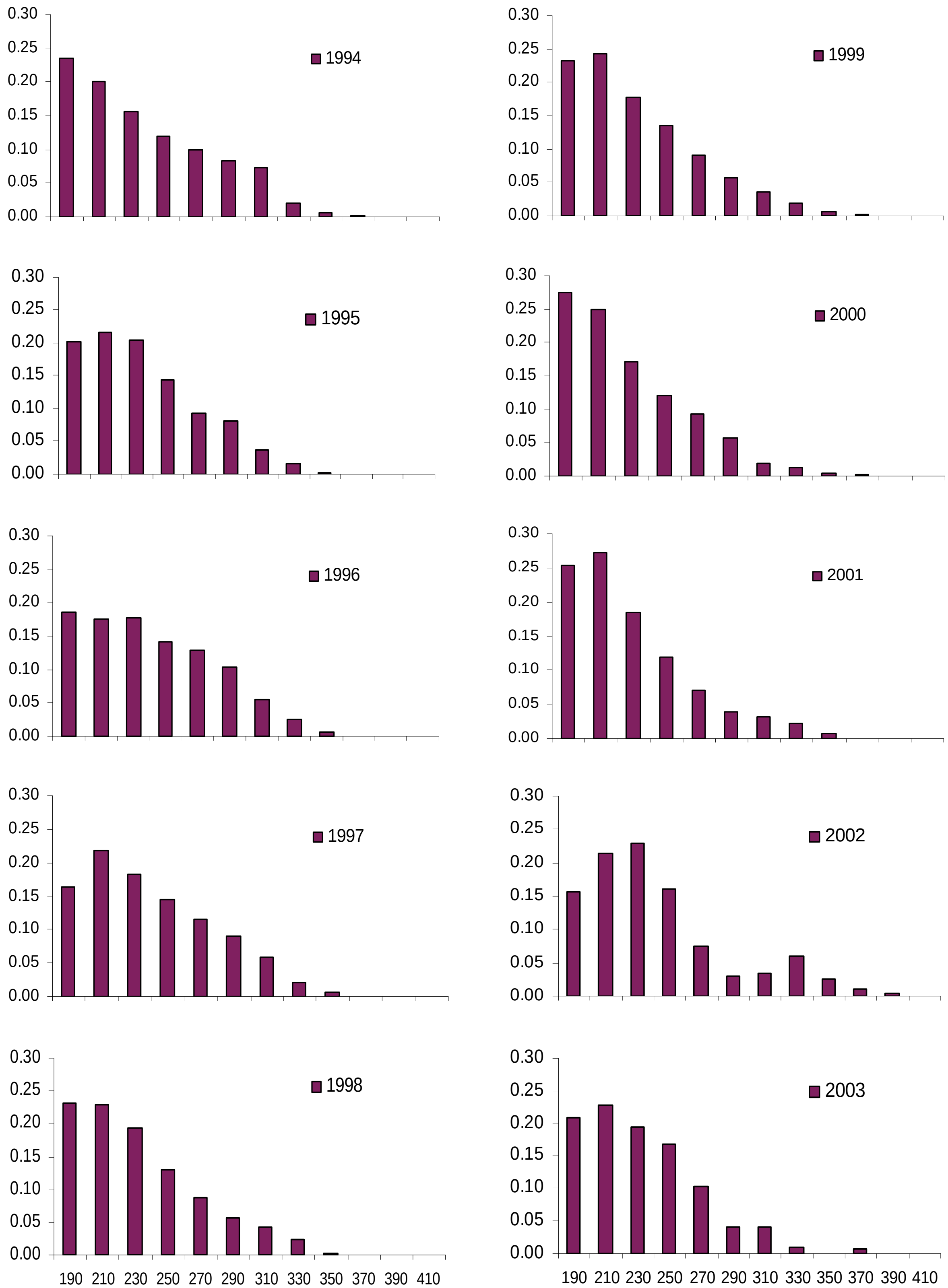


Appendix B5.–Cumulative fraction of fork lengths (mm) of cutthroat trout marked versus fork lengths recaptured, Baranof Lake, 1994–2003.



Appendix B6.–Estimated length composition (y axis = percent frequency) at Baranof Lake, 1994–2003. Lengths (x axis) are the mid-point of 20 mm FL intervals beginning at 180 mm (180 to <200 mm, 200 to <220 mm, etc)).



Appendix B7.–Estimated age (x axis) and percent composition (y axis) at Baranof Lake, 1994, 1998 and 2003.