Fishery Data Series No. 94-48

Abundance and Size of Cutthroat Trout in Wilson Lake, 1993

by

Stephen H. Hoffman

and

Robert P. Marshall

November 1994

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 94-48

ABUNDANCE AND SIZE OF CUTTHROAT TROUT IN WILSON LAKE, 1993[1]

by

Stephen H. Hoffman
and
Robert P. Marshall

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

November 1994

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-8, F-10-9, Job No. R-1-7.

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A mark-recapture experiment was used to estimate abundance of cutthroat trout *Oncorhynchus clarki* in Wilson Lake near Ketchikan, Alaska, in 1993. Abundance of cutthroat trout ≥180 millimeters fork length was 7,314 (standard error 807). Fish were captured with hook and line and large baited minnow traps. Fish caught with hook and line averaged 264 millimeters fork length; the largest was 535 millimeters. Fish caught in large baited minnow traps averaged 270 millimeters fork length; the largest was 525 millimeters. Only two "trophy-size" cutthroat trout (508 millimeters [20 inches] total length) were caught in 66 angler days of sampling, supporting anecdotal evidence that trophy-size fish are no longer abundant in Wilson Lake.

KEY WORDS: Wilson Lake, cutthroat trout, *Oncorhynchus clarki*, capture techniques, abundance estimate, size information.

INTRODUCTION

Wilson Lake is located in upper Smeaton Bay, 101 km east of Ketchikan, Alaska (Figure 1) at an elevation of 78 m. Access to the lake is via small float planes with the majority of use originating from Ketchikan. The lake is 11 km long and has a surface area of 534 hectares, a maximum depth of 108 m, and a mean depth of 51 m. The inlet stream is 22 km long. The outlet, known as Wilson River, is 18 km long and has waterfalls 2.2 km and 4.4 km below the lake which block upstream migrations of anadromous fish.

Wilson Lake is known for it's outstanding cutthroat trout *Oncorhynchus clarki* fishing. The lake historically has produced many trophy-size (>3 lb) fish, including the current state record of 8 lb 6 oz, caught in 1977.

In recent years, harvest and effort appear to have declined. No trophy fish have been reported since 1987 and data from the Alaska Department of Fish and Game (ADF&G) Statewide Harvest Survey since 1984 suggest small but variable annual harvests as large as about 600 trout in 1985 and 1986 (Mike Mills, ADF&G, Anchorage, personal communication). Secondly, the number of visitor days at two U.S. Forest Service (USFS) cabins on Wilson Lake has declined about 50 percent over the last seven years (Yvonne Stanley, USFS, Ketchikan, personal communication). This decrease has been attributed to poor fishing.

Based on this information, the Department in 1992 issued an Emergency Order prohibiting retention of cutthroat trout and the use of bait, in an effort to increase size overall abundance and the number of trophy sized fish. These regulations were effective in eliminating all harvest in 1992 and 1993 (Mills 1993, 1994), but they were opposed by some anglers who believe the lake should be managed for high rates of harvest on smaller fish rather than trophy fish production.

To best manage this fishery, more data on abundance and size of cutthroat trout in Wilson Lake was needed. The research objective in 1993 was to estimate size and abundance of cutthroat trout ≥180 mm fork length (FL).

METHODS

Abundance of cutthroat trout in Wilson Lake was estimated using a two-event mark-recapture experiment. Three sampling periods were used to mark and sample fish. The first two periods (June 11-19 and June 24-July 2) were considered the first sampling event (event 1), and the third period (July 20-29) constituted the second sampling event (event 2). A fourth sampling trip (August 4-14) was also made, but was unproductive due to problems with the data collected.

During the first sampling event (periods 1 and 2), cutthroat trout ≥180 mm FL in good physical condition were captured with funnel traps and sport fishing gear, tagged with a uniquely numbered Floy FTF-69 Fingerling Tag, sampled for scales, measured to the nearest 1 mm FL, and returned to the lake. Adipose fin clips (period 1) and shallow clips from the top of the caudal fin (period 2) were used as secondary marks to provide means for controlling for tag loss.

During the second sampling event (period 3), cutthroat trout ≥180 mm FL were again captured with funnel traps and sport fishing gear, inspected for tags and secondary marks, and scale sampled. All fish were to be measured for length

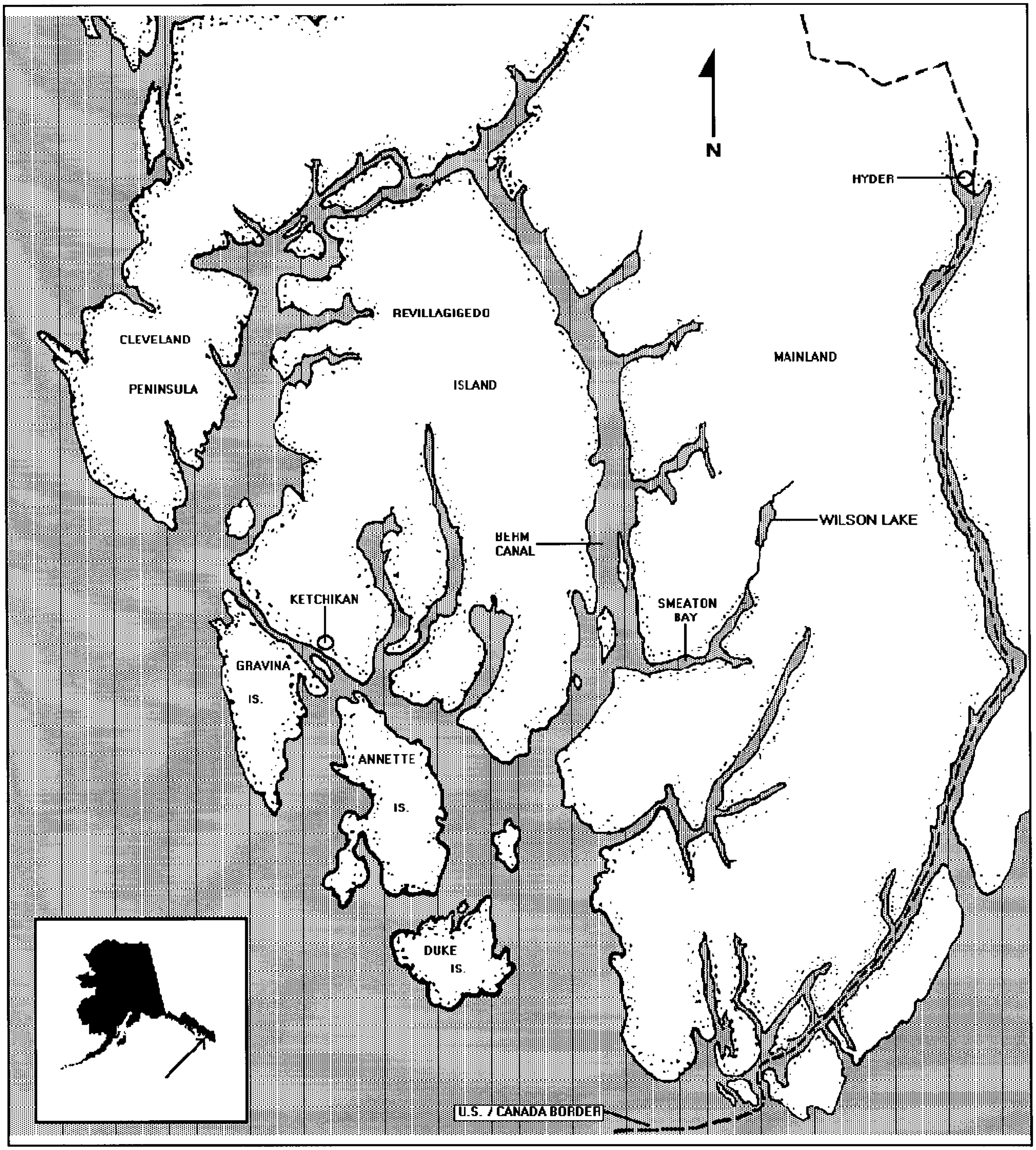

Figure 1. Wilson Lake, southern Southeast Alaska.

but during operations only previously untagged fish were measured. To prevent double sampling, fish were also to be marked with a shallow clip from the bottom of the caudal fin, but only tagged fish were actually marked. Thus, double sampling of some unmarked fish occurred. A correction for this sampling error was estimated from the (relatively low) frequency which previously marked fish were captured more than once in period 3.

Captured cutthroat trout <180 mm FL were only counted and returned to the lake during sampling. The ≥180 mm length cut-point is used in similar studies in Southeast Alaska (e.g., Jones et al. 1992), and was selected to approximate the lower size at which anglers were harvesting cutthroat trout.

During the first two 10-day sampling periods, sampling gear was systematically moved through nine sampling areas (Figure 2) on a daily basis to achieve a relatively uniform overall distribution of the gear across "shallow" (1-30 m) and "deep" (30-108 m) areas of the lake. In Wilson Lake, ~71 percent of the lake's surface area occurs over depths greater than 30 meters (Figure 2). Thus, to insure each fish had a reasonable probability of being marked[1], 50 percent of the baited funnel traps were set in shallow areas, and 50 percent were set in deep areas during event 1 (yielding a higher density of traps near the lake perimeter). During sampling event 2, traps were not set at depths over 30 m.

The number of traps set in each of the nine areas of the lake was proportional to the amount of lake surface present (Table 1), yielding a total effort of 216 trap-sets per sampling trip in event 1 and 108 per trip in event 2. The distribution of traps into each sampling area was determined by haphazardly selecting a relatively uniform distribution of locations on enlarged maps of each lake area prior to sampling. Traps set in waters ≤30 m deep were set on lake bottom. Traps set in waters >30 m deep were attached to a vertical line fixed between a weight resting on lake bottom and a buoy floating below lake surface. Portable fathometers were used to measure the depths at which traps were set.

Funnel traps were 1.5 m in length and 0.6 m in diameter, with an 8-cm-diameter opening at each end of the trap, and a mesh size of 64 mm (Jones et al. 1992). Betadine-treated salmon eggs, herring, and shrimp were used as bait in the large traps. Roughly one to two hours were spent capturing fish with sport fishing gear in each area; small lures were used as bait.

The probability that fish of different sizes were captured with equal probability during the second sampling event was estimated with a contingency table (chi-square) analysis. If size selectivity was indicated (Bernard and Hansen 1992, p. 17), the mark-recapture data was stratified into size groups using a series of contingency table analyses.

The assumption that fish had an equal chance of being marked or that complete mixing (of marks) occurred between sampling events was evaluated by testing if (given *some* mixing between areas) marked fish were recovered with equal probability in each of three broad regions (ends and middle) of the lake. End regions were composed of areas 1-3 and 7-9; the middle region was areas 4-6. If this was

[1] Data from Florence Lake show that most cutthroat trout are captured in less than about 90 feet of water (Roger Harding, ADF&G, personal communication). Experiences at other large, deep lakes, also suggested sampling (setting baited traps on the lake bottom) would produce similar results.

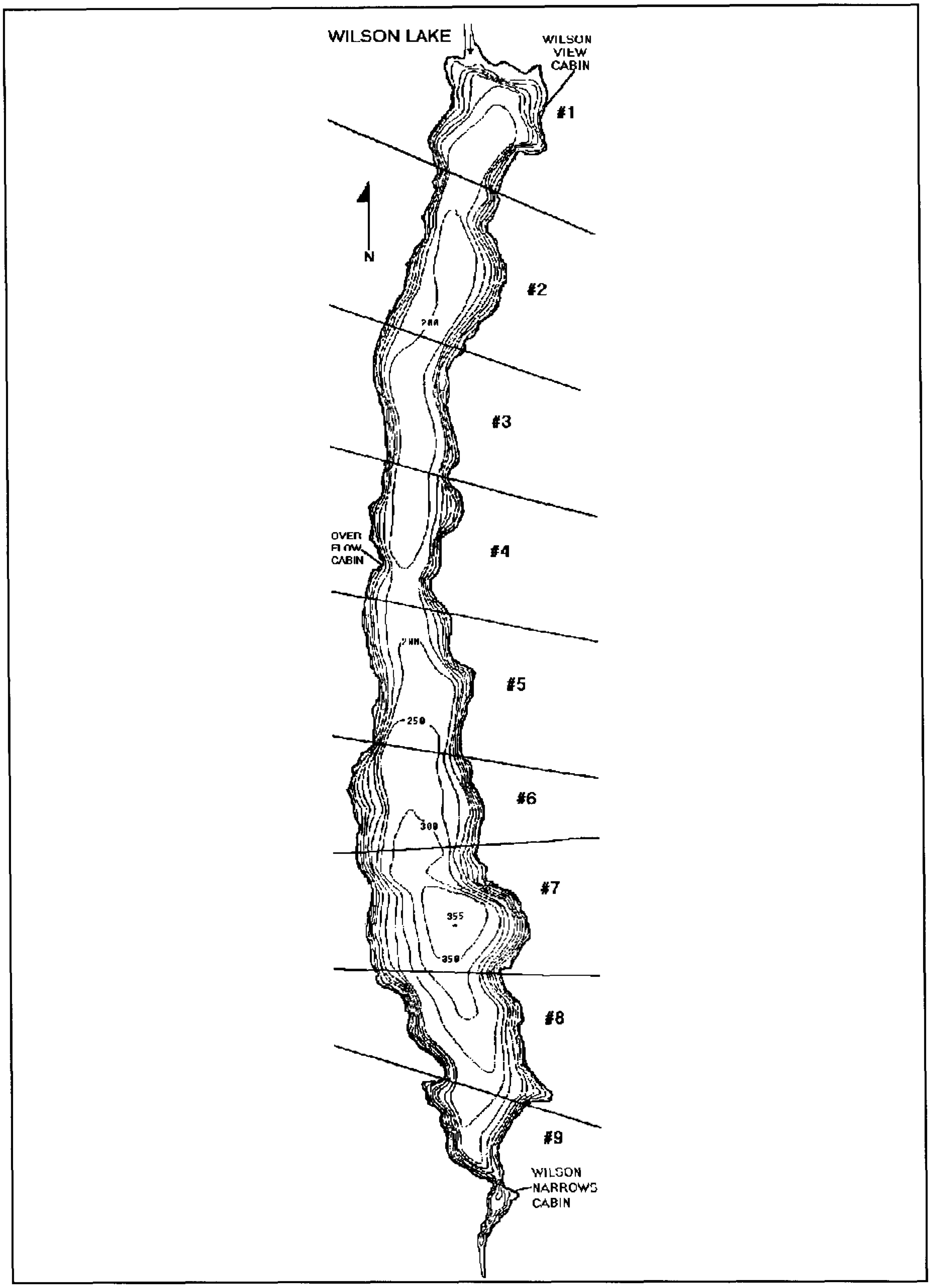

Figure 2. Bathymetric map of Wilson Lake, southern Southeast Alaska, showing sampling areas used in the 1993 cutthroat trout study.

Table 1. Distribution of baited funnel traps to capture cutthroat trout at Wilson Lake, 1993, by sampling area. Lake areas are approximate.

	Lake area 0- to 30-m depth			Lake area 30- to 108-m depth		
Sampling area	Area (km^2)	Proportion	No. traps	Area (km^2)	Proportion	No. traps
Area 1	0.239	0.210	23	0.175	0.063	7
Area 2	0.119	0.105	11	0.303	0.109	12
Area 3	0.087	0.077	8	0.305	0.110	12
Area 4	0.132	0.116	22	0.281	0.101	11
Area 5	0.102	0.090	10	0.324	0.117	13
Area 6	0.099	0.087	9	0.376	0.136	15
Area 7	0.118	0.104	11	0.519	0.187	20
Area 8	0.112	0.099	11	0.355	0.128	14
Area 9	0.129	0.113	12	0.133	0.048	5
Total	1.137	1.000	108	2.769	1.000	108

not so, a Darroch estimator (Seber 1982, Darroch 1961) was used to estimate

$$\underline{U} = \mathbf{D_u} \mathbf{M}^{-1} \underline{a} \tag{1}$$

where $\underline{U}$ = vector of the estimated number of *unmarked* fish in each area during the second sampling event,

$\mathbf{D_u}$ = diagonal matrix of the number of *unmarked* fish captured in each area during the second sampling event,

$\mathbf{M}$ = matrix (m_{ij}) of the number of tagged fish recovered in area (j) which were released in area i, and

$\underline{a}$ = vector of the number of tagged fish released in area i;

and abundance $\hat{N} = U + A$ where U and A are the sums of the vector elements in $\underline{\hat{U}}$ and $\underline{\hat{a}}$, respectively. The variance-covariance matrix was estimated using the approximation for $E[(\underline{\hat{U}}-\underline{U})(\underline{\hat{U}}-\underline{U})^T]$ as explained by Seber (1982).

If marked-to-unmarked ratios were equal across areas, the Chapman estimators (Seber 1982) were used to estimate abundance:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1 \tag{2}$$

$$V[\hat{N}] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{3}$$

where $\hat{N}$ = abundance of cutthroat trout, n_1 = number of fish marked and released in the first sampling event, n_2 = number of fish inspected for marks in the second sampling event, and m_2 = number of marked fish recaptured in the second sampling event.

RESULTS

During the four 10-day sampling trips, 3,247 cutthroat trout and 2,826 Dolly Varden were captured. Large funnel traps and hook and line gear accounted for 1,893 and 1,354 cutthroat trout, respectively; all Dolly Varden were captured in large traps (Table 2). A total of 763 cutthroat lengths from event 1 and 999 from event 2 were used to test for size selective sampling (Table 3, Figure 3). Cutthroat trout sampled in event 1 were slightly larger than those sampled in event 2. The mean fork length of fish sampled using large traps was 270 mm and ranged from 180 to 525 mm. The mean fork length of hook and line sampled fish was 264 mm and ranged from 180 to 535 mm (Table 3). A total of 766 fish from event 1 and 1,076 from event 2 were used for abundance estimates (Table 4).

Age compositions for cutthroat trout were not compiled for this report because recent research showed ages estimated from scales collected at Florence Lake were unreliable (Jones et al. 1992). We have thus temporarily stopped aging cutthroat trout age pending completion of an extensive study to improve the procedures.

Table 2. Sampling effort (hours), catch, and catch-per-unit-effort (CPUE, fish per hour) by period, gear and species, Wilson Lake, 1993.

			Cutthroat trout[a]		Dolly Varden	
Period[b]	Gear	Effort	Catch	CPUE	Catch	CPUE
1	Hook & line	74	195	2.64	--	--
	Large trap	3,145	147	0.04	301	0.09
2	Hook & line	82	233	2.84	--	--
	Large trap	4,239	173	0.04	483	0.11
3	Hook & line	108	433	4.01	--	--
	Large trap	9,751	684	0.07	736	0.08
4[c]	Hook & line	108	493	4.57	--	--
	Large trap	4,863	889	0.18	1,306	0.27
Total	Hook & line	372	1,354	3.64	--	--
	Large trap	21,998	1,894	0.09	2,826	0.13

[a] Includes all cutthroat trout ≥180 mm FL captured.

[b] Period 1 = 10-19 June; Period 2 = 24 June to 2 July; Period 3 = 20-30 July; Period 4 = 4-12 August.

[c] Catches during period 4 were not used for the size and abundance estimates.

Table 3. Cutthroat trout fork length data for large trap and hook-and-line sampling gear during events 1 and 2, Wilson Lake, 1993[a].

	Event 1	Event 2	Total
Sample size	764	999	1,763
Mean length (mm)	270	265	
Minimum length (mm)	180	180	
Maximum length (mm)	470	525	
SD of lengths (mm)	43	42	
	Large trap	**Hook and line**	**Total**
Sample size	870	893	1,763
Mean length (mm)	270	264	
Minimum length (mm)	180	181	
Maximum length (mm)	525	458	
SD of lengths (mm)	44	42	

[a] Cutthroat captured during period 4, including one fish 535 mm in length caught with hook and line, not included.

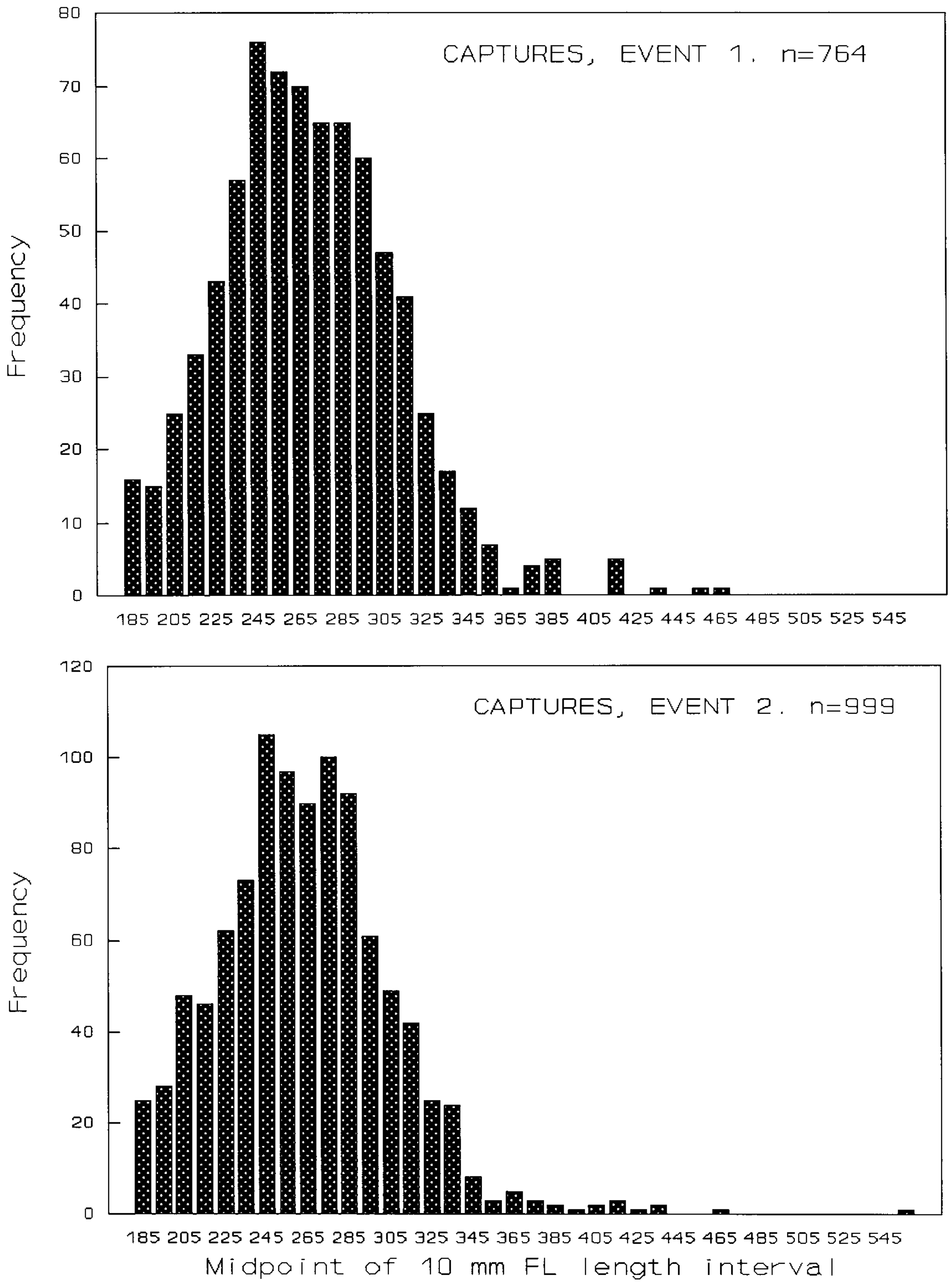

Figure 3. Length frequencies for cutthroat trout caught during sampling event 1 (top) and sampling event 2 (bottom), Wilson Lake, 1993.

Table 4. Summary of cutthroat trout tagging and recovery data for fish ≥180 mm FL, used for abundance estimates Wilson Lake, 1993. Periods 1 and 2 are event 1; period 3 is event 2.

	1993 sampling periods		
	Event 1		Event 2
	Period 1 11 June- 19 June	Period 2 24 June- 2 July	Period 3 20 July- 29 July
Newly tagged fish released alive	323	443	---
Mortalities	2	4	2
Captured, not tagged, released alive	2	1	956
Recaptures:			
with tags from Period 1	5[b]	12[b]	28
Period 2	---	4[b]	43
without tags from Period 1	1[b]	9[b]	33
Period 2	---	---	14
Total catch	327	448	1,076

[a] Not counted in Total catch.

[b] Recovery of clipped fish from period 1 may not have been consistently recorded during event 1.

Age composition estimates for Wilson Lake will be determined when an improved algorithm is available for estimating ages from scales.

Seven hundred sixty-six (766) cutthroat trout between 180 mm and 470 mm FL were tagged and released alive in event one (Table 4). During event two, 1,076 cutthroat trout between 180 mm FL and 545 mm FL were inspected for marks; 118 of these fish (71 + 47) had been "marked" in the first sampling event, but 47 (or 40 percent of the 118) had lost their primary, numbered tag (Table 4). Fish measured for length during event 2 included 954 of the 956 unmarked, 18 of the 71 tagged, and 25 of the 47 marked fish from event 1 that had lost their tags. Later, the lengths of the 53 (71 - 18) recaptured (tagged) fish that were not measured for length were assumed to be as when tagging occurred.

The distribution of lengths of fish recaptured in event 2 differed from distribution of lengths marked in event 1 (Table 5), suggesting the second sampling event was size-selective ($\chi^2 = 7.5$, df = 2, P = 0.024). A series of hypothesis tests identified two size groups that had equal probabilities of capture: "small" (180-240 mm FL) and "large" (≥241 mm FL). Similar size-selective sampling is apparent in other studies in Southeast Alaska which use the same sampling gear and an 180 mm FL cut-point (e.g, Jones et al. 1992, Jones and Harding 1991).

Grouping the recovery data (Table 5) into these two size classes leads to estimates of probabilities for recapturing both small (P = 0.069) and large (P = 0.144) tagged fish between events 1 and 2. These probabilities can be used to allocate 22 unmeasured fish that had also lost their tag into the two size classes; approximately 3 were small and 19 were large. These estimates were used in subsequent calculations to minimize bias. However, adding these tagged fish into their respective size groups changes slightly the estimated probabilities for recapturing small and large fish from event 1 to event 2; recalculation yields new probabilities for small (P = 0.086) and large (P = 0.177) fish. These probabilities (0.086, 0.177) were thus used (below) to allocate the estimated number of unmarked fish sampled twice in event 2 into the two size categories. Also, after all 118 recaptured fish were assigned to size categories, the final chi-square statistic in Table 5 was recalculated to confirm the two size groups were appropriate ($\chi^2 = 9.4$, df = 1, P = 0.002).

The extent to which unmarked fish were sampled twice in event 2 was estimated from double sampling of marked fish. Eight of the 118 marked fish sampled in event 2 (6.8 percent) were also captured a second time, as evidenced by a lower caudal clip. Assuming the estimated relative probabilities of recapturing small (P = 0.086) and large (P = 0.177) marked fish (above) apply to unmarked fish, it is easily shown that an estimated 0.6 of 8 marked fish are likely to be small, and 7.4 are likely to be large (in fact, 7 were large and one was not measured). Application of this model to the 956 unmarked fish sampled in period 2 (Table 4) suggests that 9 (of 272) small fish, and 45 (of 684) large fish were sampled twice in period 2. Thus, these numbers of unmarked fish were removed from subsequent calculations to minimize bias.

Some mixing of fish between sampling areas did occur between sampling events (Tables 6 and 7). The hypothesis of equal probability of capture by area was rejected for both large and small fish (P ≤ 0.019 for small and P ≤ 0.016 for large fish, Tables 8 and 9), suggesting Darroch's estimators should be used to estimate abundance. However, the recovery matrix for small fish (Table 6) is much too sparse to use Darroch's estimator, so the Petersen estimator ($n_1 = 189$, $n_2 = 279$, $m_2 = 16$) was used for small fish.

Table 5. Results of chi-square tests to determine cutthroat trout size categories for stratifying the mark-recapture experiment in Wilson Lake, 1993.

Length category	Length mm (FL)	Number recaptured[a]	Number not recaptured	Proportion recovered
I	180-240	13	176	0.068
II	241-300	60	348	0.147
III	301-360	22	127	0.148
IV	361-420	0	15	---
V	421-480	1	2	---

[a] Excluding 22 marked fish recaptured without numbered tags and not measured.

Hypothesis A: (size class III* = classes III, IV, and V pooled)

$H_0 = P_I = P_{II} = P_{III}^*$.

Result: $\chi^2 = 7.5$, $df = 2$, $p = 0.024$; reject H_0.

Hypothesis B:

$H_0 = P_{II} = P_{III}^*$.

Result: $\chi^2 = 0.084$, $df = 1$, $p = 0.77$; accept H_0.

Hypothesis C:

$H_0 = P_I = (P_{II}+P_{III}^*)$.

Result: $\chi^2 = 7.4$, $df = 1$, $p = 0.007$; reject H_0.

CONCLUSION: Stratify experiment by two size classes: $P_{(I)}$ = 180-240 mm, and $P_{(II+III+IV+V)}$ = ≥241 mm FL.

Table 6. Number of marked and unmarked cutthroat trout 180-240 mm FL captured by tagging and recovery area (m_{ij}), marked by area (a_i), and unmarked captures by area (u_j), sampling event 2, Wilson Lake, 1993.

	Recovery area			
Tagging area	A[a,d]	B[b,d]	C[c,d]	a_i
A		1		81
B		4		56
C			2	52
u_j[e]	137	63	63	

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

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

[c] Study areas 7, 8, and 9.

[d] Also recovered in areas a, b, and c, respectively, were 2, 2, and 2 marked small fish that had lost their numbered tag, and 6, 10, and 6 marked fish that had lost their numbered tag but were not measured for length.

[e] After removing 5, 2, and 2 unmarked small fish estimated to have been sampled twice in areas a, b, and c, respectively, during period 3.

Table 7. Number of marked and unmarked cutthroat trout 241-525 mm FL captured by tagging and recovery area (m_{ij}), marked by area (a_i), and unmarked captures by area (u_j), sampling event 2, Wilson Lake, 1993.

	Recovery area			
Tagging area	A[a]	B[b]	C[c]	a_i
A	12	9	3	212
B	2	18	2	197
C	3	2	13	166
u_j[e]	258	213	167	

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

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

[c] Study areas 7, 8, and 9.

[d] Also recovered in areas a, b, and c, respectively, were 5, 11, and 3 marked large fish that had lost their numbered tag, and 6, 10, and 6 marked fish that had lost their numbered tag but were not measured for length.

[e] After removing 19, 15, and 12 unmarked large fish estimated to have been sampled twice in areas a, b, and c, respectively, during period 3.

Table 8. Number of marked and unmarked cutthroat trout 180-240 mm FL captured in sampling event 2, by recovery area, Wilson Lake, 1993.

	Recovery area			
	A[a]	B[b]	C[c]	Total
Marked fish	2	7	4	13
Unmarked fish	137	63	63	263
Total	139	70	67	276

$\chi^2 = 7.9$, df = 2, $P \leq 0.019$

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

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

[c] Study areas 7, 8, and 9.

Table 9. Numbers of marked and unmarked cutthroat trout 241-525 mm FL captured in sampling event 2, by recovery area, Wilson Lake, 1993.

	Recovery area			
	A[a]	B[b]	C[c]	Total
Marked fish	22	40	21	83
Unmarked fish	258	213	167	638
Total	299	268	200	721

$\chi^2 = 8.3$, df = 2, $P \leq 0.016$

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

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

[c] Study areas 7, 8, and 9.

The abundance of cutthroat trout from 180 mm FL through 240 mm FL was $\hat{N}$ = 3,128, SE[$\hat{N}$] = 682. The abundance estimate for fish above 240 mm FL was $\hat{N}$ = 4,186, SE[$\hat{N}$] = 431. Abundance of all cutthroat trout above 180 mm FL is $\hat{N}$ = 7,314, SE[$\hat{N}$] = 807. Relative precision for the estimate is thus about ±22 percent for a 95 percent confidence interval. To apply Darroch's estimator, an estimated 38 large fish that had lost their tag (so that the marking area was unknown) were assigned to marking area a, b, or c using the naive probabilities (Table 7) that a fish was marked in an area *given* it's recovery area, which was known for each fish.[2] This and other steps taken to minimize bias add an unknown, but hopefully not large, degree of uncertainty to the estimates.

Because our gear is size selective (Table 5), the distribution of lengths for sampled fish (Figure 3) are not representative of the population in lake. In particular, fish below about 240 mm FL are under-sampled, and the gear is highly selective at the smaller sizes, as demonstrated in Figure 3. The abundance estimates are that 57.2 percent of the population ≥180 mm FL (4,186/7,314) is above 240 mm FL, and 42.8 percent is below 240 mm FL. These estimates can be used in conjunction with the sampled length frequency data (Figure 3) to calculate unbiased length compositions for some intervals of interest in this experiment. In particular, unbiased estimates are possible above the length where size selectivity is no longer important; below this point (about 240 mm FL at Wilson Lake, Table 5), estimates for intervals smaller than the 180 mm - 240 mm size interval will be biased and are probably pointless[3].

To select appropriate sampling data for the length composition estimates, abundance was recalculated with Darroch's model after pooling data to eliminate stratification by size. Since the (biased) pooled-data estimate ($\hat{N}$ = 11,292, SE[$\hat{N}$] = 1,860) was significantly different from the result with stratification ($\hat{N}$ = 7,314), length compositions should be based on both sampling events when the distributions of lengths sampled during both events are similar (Bernard and Hansen 1992, p. 17). A KS test of this hypothesis is rejected (d = 0.69, P = 0.03), but the difference in the distributions is functionally small (Figure 4, Table 3). We thus used lengths from both events to estimate size compositions (Table 10), and greatly increased the sample sizes for the larger size-classes.

About 15 percent of the cutthroat trout in Wilson Lake are ≥300 mm FL, 3.1 percent are ≥340 FL, and 1.2 percent are ≥380 mm FL (Table 10).

Investigation of the observed difference in length distributions by sampling event showed that fish caught in traps in event 1 ($\bar{x}$ = 279 mm FL, SE[$\hat{N}$] = 2.6 mm) were significantly larger than fish caught with hook and line in event 1 ($\bar{x}$ = 266 mm FL, SE[$\hat{N}$] = 1.9 mm), and also larger than fish caught in event 2 with either traps ($\bar{x}$ = 266 mm FL, SE[$\hat{N}$] = 1.8 mm) or hook and line ($\bar{x}$ = 263 mm FL, SE[$\hat{N}$] = 2.0 mm). These differences would result if fish residing in deeper areas of the lake tended to be larger than in shallow areas, because: a) traps were set in deep (>30 m) areas only during the first sampling event, and b) hook and lines were not fished intensely in the deep, offshore regions of the lake.

---

[2] Final estimates of m_{ij} in the tag-recovery matrix (Table 6) are, by rows: 19.1, 15.2, 4.3 (row a); 3.2, 30.4, 2.9 (row b); and 4.8, 3.4, 18.8 (row c).

[3] In principle, a selectivity curve for any length intervals of interest can be obtained from mark recapture (MR) data. However, MR data from Wilson Lake is too sparse to resolve a curve in small intervals; see Table 5.

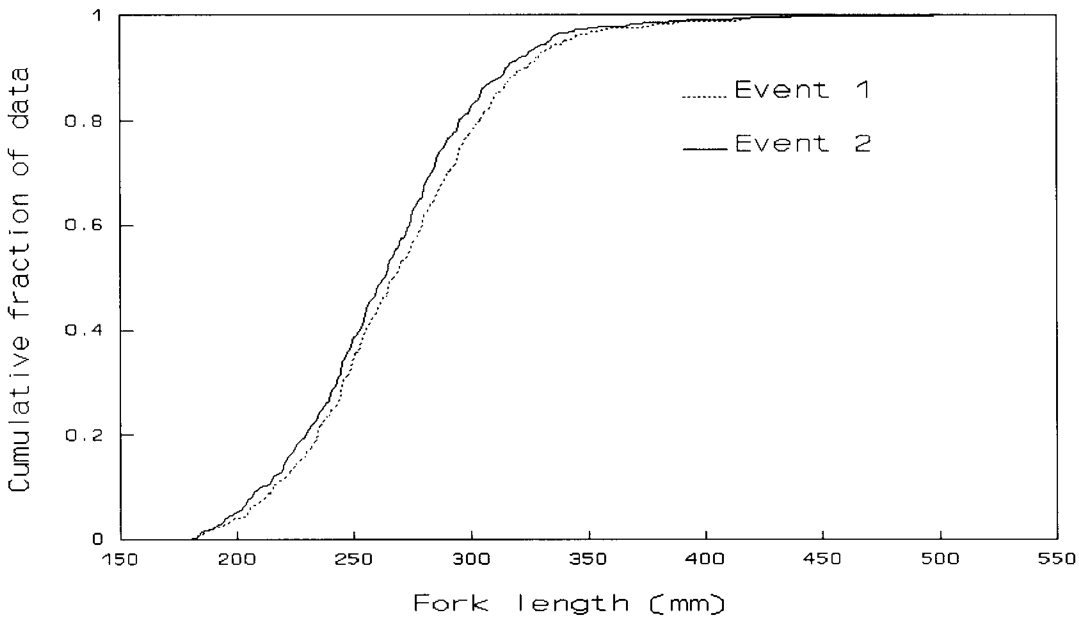

Figure 4. Cumulative number of cutthroat trout captured by fork length and sampling event, Wilson Lake, 1993.

Table 10. Numbers of cutthroat trout ≥180 mm FL captured by 20 mm FL length intervals, Wilson Lake, 1993.

Interval	C_i Catch in interval	N_i Population in interval ±SE [a]	Cumulative % of population ≥180 mm FL	Percent of population ≥180 mm FL that is longer
≤ 240	470	3128 ± 682	42.8	57.2
240-260	350	1133 ± 128	58.3	41.7
260-280	326	1055 ± 120	72.7	27.3
280-300	278	900 ± 104	85.0	15.0
300-320	179	580 ± 72	92.9	7.08
320-340	91	295 ± 42	96.9	3.05
340-360	30	97 ± 20	98.3	1.73
360-380	13	42 ± 12	98.8	1.15
380-400	8	26 ± 9	99.2	0.80
400-420	10	32 ± 11	99.6	0.35
420-440	4	13 ± 7	99.8	0.18
≥ 440	4	13 ± 7	100.0	---

[a] $\hat{N}_i = \hat{N} \cdot (C_i / \sum C_i)$ where i is length interval for fish ≥240 mm FL, and $SE(N_i) = \sqrt{Var(\hat{N})}$ is computed using the formula for the variance of a product of 2 independent random variables (Goodman 1960).

DISCUSSION

The accurate use of Petersen estimators requires several assumptions, including that *both* immigration (or growth recruitment) and emigration (or death) do not occur during the experiment. We minimized the likelihood of a significant violation of this assumption by keeping the two sampling events relatively close together (the midpoints of the 2 events were about 4 weeks apart). Also, the distributions of lengths of fish captured with hook and lines in event 1 (n = 477) and event 2 (n = 416) are not different (d = 0.04, P = 0.79) so growth recruitment is not apparent. The abundance estimate is thus germane to the first sampling event (since deaths may have occurred). Hook and line gear was used for the test because it was fished most similarly during both sampling events.

Another assumption is that all fish have the same probability of capture during the first sample <u>or</u> in the second sample <u>or</u> that marked and unmarked fish mix completely between the two sampling events. In Wilson Lake, the experiment was stratified to equalize probabilities of capture for fish of different size, and a Darroch estimator was used to adjust for partial mixing across geographic areas of the lake as possible (the large-sized fish). Although Darroch's model could not be used for small fish, abundance of large fish calculated with Darroch (4,186) and Petersen (4,143) models are nearly identical; this suggests large differences between Darroch and Petersen estimates for small fish are unlikely.

Three unusual problems developed during this experiment: high tag loss, failure to mark unmarked fish in period 2 to prevent double sampling, and failure to take length measurements from all fish recaptured in period 2. Because marked fish did have a secondary mark, the effect of tag loss is to add bias to the Darroch model point estimate for large fish, and bias it's variance estimate downward. However, abundance estimates for large fish from the Darroch and Petersen models (see above) are nearly identical, so the bias here is probably small. Failure to prevent double sampling of unmarked fish during event 2 adds bias to both the Darroch and Petersen model estimates. This bias is probably also small, since observations from recaptures of marked fish could be used to estimate and adjust for the apparently small amount of double sampling. The failure to take length measurements from all marked fish recaptured in event 2, coupled with the loss of tags, meant that assumptions of the experiment were tested with reduced power, and the possibility of some bias.

While the direction of the bias in point estimates is unknown (but hopefully small), the variances are most certainly biased low. An estimate of the true relative precision of the experiment could presumably be made using a bootstrap simulation (Efron 1982). This was not attempted since the estimated (although biased) relative precision for the experiment is high (±22 percent for a 95 percent confidence interval) and much above that needed for routine management work. We thus felt that even a moderate loss of relative precision would not compromise the basic results and implications of this experiment.

Catch-per-unit-effort (CPUE) for funnel traps set across the lake during the first sampling event was computed for indices of relative abundance in the near-shore (≤30 m) and offshore (>30 m) regions of the lake. In the near-shore (≤30 m) area, CPUE was 0.16 (22 fish in 136 traps). In the offshore (>30 m) area, CPUE was 1.33 (285 fish in 214 traps). Since approximately 71 percent of the surface area of Wilson Lake is over water deeper than 30 m, a significant part of the population ≥180 mm FL would appear to use the offshore habitat. If the useable water depth in near-shore and offshore areas is roughly similar, then roughly 23 percent of the population ≥180 mm FL might have used the offshore areas when we sampled in June. Research to better understand the size distribution and movements of these fish will provide a better understanding of both the ecology, and the requirements of experimental designs to measure size and abundance of cutthroat trout in deep alpine lakes in Southeast Alaska.

The abundance estimate of 7,314 for Wilson Lake (for an overall density of about 14 per hectare) for cutthroat trout ≥180 mm FL is substantial for Southeast Alaska. Florence Lake, for example, is among the most productive large lakes we have carefully investigated with respect to cutthroat trout production; it has about 9,000 and a density of about 28 cutthroat trout ≥180 mm FL per hectare (Jones and Harding 1991; Jones et al. 1992, Harding and Jones 1993). Hasselborg Lake has also been studied at length; it has approximately 9,000 and a density of about 7 cutthroat trout ≥190 mm FL per hectare (Mark Laker, USFS, Juneau, personal communication; Jones et al. 1992). Another large lake that has been studied is Turner Lake; it has approximately 1,200 and a density of about 1 cutthroat trout ≥160 to 280 mm FL per hectare (Jones and Harding 1991). Of these lakes, Florence is relative shallow (<30 m) while Turner is steep sided and much deeper (215 m). The bathymetric profiles of Hasselborg and Wilson Lakes (with maximum depths of about 89 and 101 m, respectively) are intermediate to the profiles for Florence and Turner Lakes. Also, relatively high exploitation rates (25 percent) at Turner Lake (Jones and Harding 1991) may have significantly reduced abundance of cutthroat trout, especially the large fish, in that system.

The production of resident cutthroat trout in Southeast Alaska lakes is obviously not a simple function of lake surface area and bathymetry, however. For example, the production of cutthroat trout in small (<50 hectare) Southeast Alaska lakes may also depend on the production of other species in the lake, such as kokanee, Dolly Varden, and anadromous fishes (Schmidt 1994). Similarly, a recent study at Baranof Lake (324 hectares), which contains only cutthroat trout, indicates a population of about 12,000 cutthroat trout ≥180 mm FL, or about 38 cutthroat trout per hectare (John DerHovanisian, ADFG, Juneau, personal communication).

Size selective harvesting and relatively high exploitation rates can certainly lead to a decline in relative abundance of fish in the older age-classes of a recreational fishery (Quinn and Szarzi 1994). Such a decline in Wilson Lake is indicated from anecdotal evidence of the decreased numbers of larger trout in the lake and the absence of applications for trophy fish certificates since 1987. About 1 percent of the fish ≥180 mm FL we sampled with hook and lines in 1993 were over 400 mm FL, and only 2 (<0.1 percent) of the total number of unique fish caught with all gear types during 1993 were trophy-sized fish. These statistics, and the length composition estimates (Table 10), are not easily translated into measures of success for knowledgeable anglers targeting on large, or trophy fish. However, the statistics make it clear that large cutthroat trout are a very minor component of the population in Wilson lake. Assuming estimated annual harvest rates were about 600 fish in 1985 and 1986, exploitation rates would have been about 8 percent of the 1993 abundance of fish ≥180 mm FL. Although this exploitation rate is most likely sustainable, it (along with any tendencies to harvest larger fish) appear to have been too high to maintain a productive recreational fishery for trophy-sized cutthroat trout at Wilson Lake.

ACKNOWLEDGMENTS

The Authors thank Wendy Ness, Anna Ner, Chris Varney, and Jim Foster, who conducted the field work in this study, Anne Gibb and Pauline Fletcher for data entry and typing, and Mike Wood, for the maps used in this report.

LITERATURE CITED

Bernard, D. R., and P. A. Hansen. 1992. Mark-Recapture experiments to estimate the abundance of fish. Alaska Department of Fish and Game, Fishery Data Series No. 92-4, Juneau.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-60.

Efron, B. I. 1982. The jackknife, the bootstrap, and other resampling plans. Society for Industrial and Applied Mathematics, CBMS-NSF Regional Conference Series in Applied Mathematics, No. 38.

Harding, R. D. and J. D. Jones. 1993. Cutthroat trout studies at Florence Lake, Southeast Alaska, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-44, Juneau.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Society 55: 708-713.

Jones, J. D. and R. Harding. 1991. Cutthroat trout studies: Turner/Florence Lakes, Alaska, during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-53, Juneau.

Jones, J. D., R. P. Marshall, and R. Harding. 1992. Cutthroat trout studies at Florence and Hasselborg lakes, Southeast Alaska, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-43, Juneau.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42. Anchorage, Alaska.

______. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28. Anchorage, Alaska.

Quinn, T. J., II. and N. J. Szarzi. 1994. Determination of sustained yield in Alaska's recreational fisheries. Pages 61-84 *in* G. Kruse, D. M. Eggers, R. J. Marasco, C. Pautzke, and T. J. Quinn II (editors). 1993. Proceeding of the international symposium on management strategies for exploited fish populations. Alaska Sea Grant College Program Report No. 93-02, University of Alaska Fairbanks.

Seber, G. A .F. 1982. The estimation of animal abundance and related parameters. MacMillan, New York.

Schmidt, A. E. 1994. Size and abundance of cutthroat trout in small Southeast Alaska lakes, 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-6, Juneau.