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ABSTRACT

In September and October of 1989, fyke nets were set along the shores of Big Lake in the Matanuska-Susitna Valley of Southcentral Alaska. Rainbow trout *Oncorhynchus mykiss* captured in the fyke nets were marked to facilitate a mark-recapture study to estimate the abundance of rainbow trout in the lake. The 1989 abundance estimate for rainbow trout ≥ 150 mm was 8,191. In 1989, 216,371 hatchery-reared fingerling rainbow trout of Big Lake origin were released into the lake. These fingerlings were too small in September and October of 1989 to be included in the population estimate. Rainbow trout populations in Big Lake were again sampled in September and October of 1990 with fyke nets to estimate the abundance of rainbow trout in the lake. The abundance estimate in 1990 was 7,530 fish ≥ 130 mm. The estimated number of age-1 rainbow trout ≥ 130 mm was 6,143, an estimated 2,603 of which were from the 1989 stocking.

KEY WORDS: Southcentral Alaska, Matanuska-Susitna Valley, Big Lake, rainbow trout, *Oncorhynchus mykiss*, fyke net sampling, population estimate, length, age.

INTRODUCTION

Big Lake (Figure 1) consists of several basins which total 1,151 hectares and is located in the Matanuska-Susitna Valley of Southcentral Alaska. Meadow Creek, the principal tributary of Big Lake, drains an extensive watershed that includes over 30 lakes and ponds located north and east of the lake. Minor drainages also enter from the west through Flat and Mirror (Mud) Lakes. Fish Creek, the outlet of Big Lake, flows approximately 23 km to the Knik Arm of northern Cook Inlet.

Many private residences and easy public access along the lake have contributed to the growth and popularity of a recreational fishery on Big Lake. Currently, there are 934 lake-front lots with more than 500 private lake-front cabins and residences, two state waysides, a private commercial campground, two boat marinas, and at least seven lounge and restaurant establishments (including three motels) along the shores of the lake. The lake is also the site of an Alaska Department of Fish and Game (ADFG) hatchery which produces coho salmon *Oncorhynchus kisutch* and sockeye salmon *O. nerka*.

During 1952, the U.S. Fish and Wildlife Service studied fishing pressure on Big Lake. These studies indicated that 10.9% of all sport fishing on the Alaska mainland south of the Alaska Range occurred on Big Lake (Allin 1956). During the period 1977 to 1989, fishing effort on Big Lake, as measured by a statewide postal survey, has averaged approximately 13,265 angler-days annually (Mills 1979-1990). Pronounced reductions in harvest of rainbow trout *O. mykiss* during 1983, 1984, and 1987 (Figure 2) provided the impetus for this investigation.

In 1988, 24,033 catchable-size rainbow trout of Big Lake origin were stocked into Big Lake. All of the stocked fish were marked, and as they mixed with the wild population served as the marks for a mark-recapture population estimate. The population estimate in June, shortly after the catchables were released, was 10,607 wild fish. The experiment was repeated in October, allowing more time for marked fish to mix with the wild stock, and the estimate at that time was 22,261 wild fish (Havens and Alexandersdottir 1990). These low population estimates, coupled with the reductions in harvest, led to the conclusion that the population was depressed from probable historic levels and was not sufficient to sustain current levels of sport harvest. In 1989, fingerling stocking was implemented to supplement wild production and this report presents evaluation of the fingerling stockings.

METHODS

Fingerling rainbow trout were stocked in the summer during both 1989 and 1990. In 1989, 216,371 fingerlings were released, of which 72,000 or 33% were adipose finclipped. In 1990, 449,627 fingerlings were released, of which 76,869 or 17% were adipose finclipped. Adipose finclips were used to estimate the hatchery component of the total population estimate.

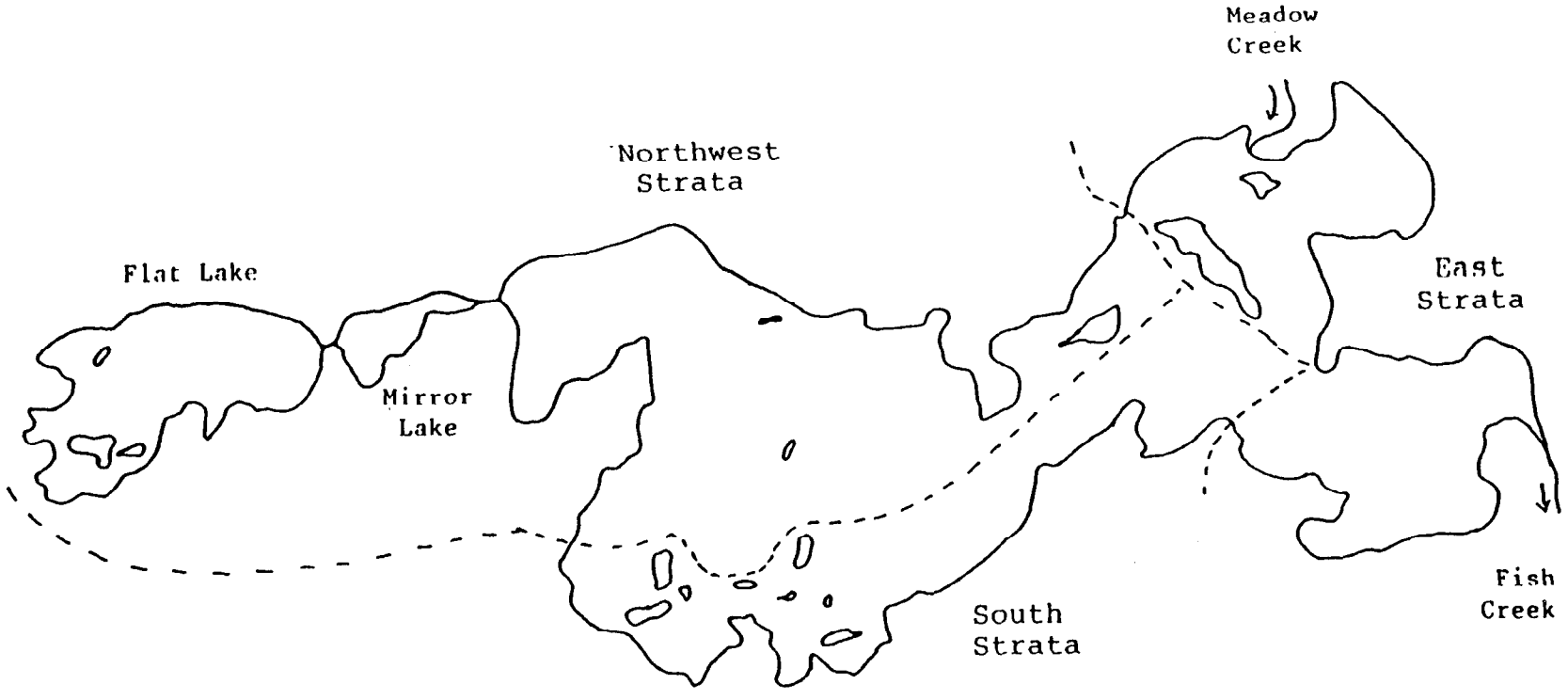

Figure 1. Map of Big Lake.

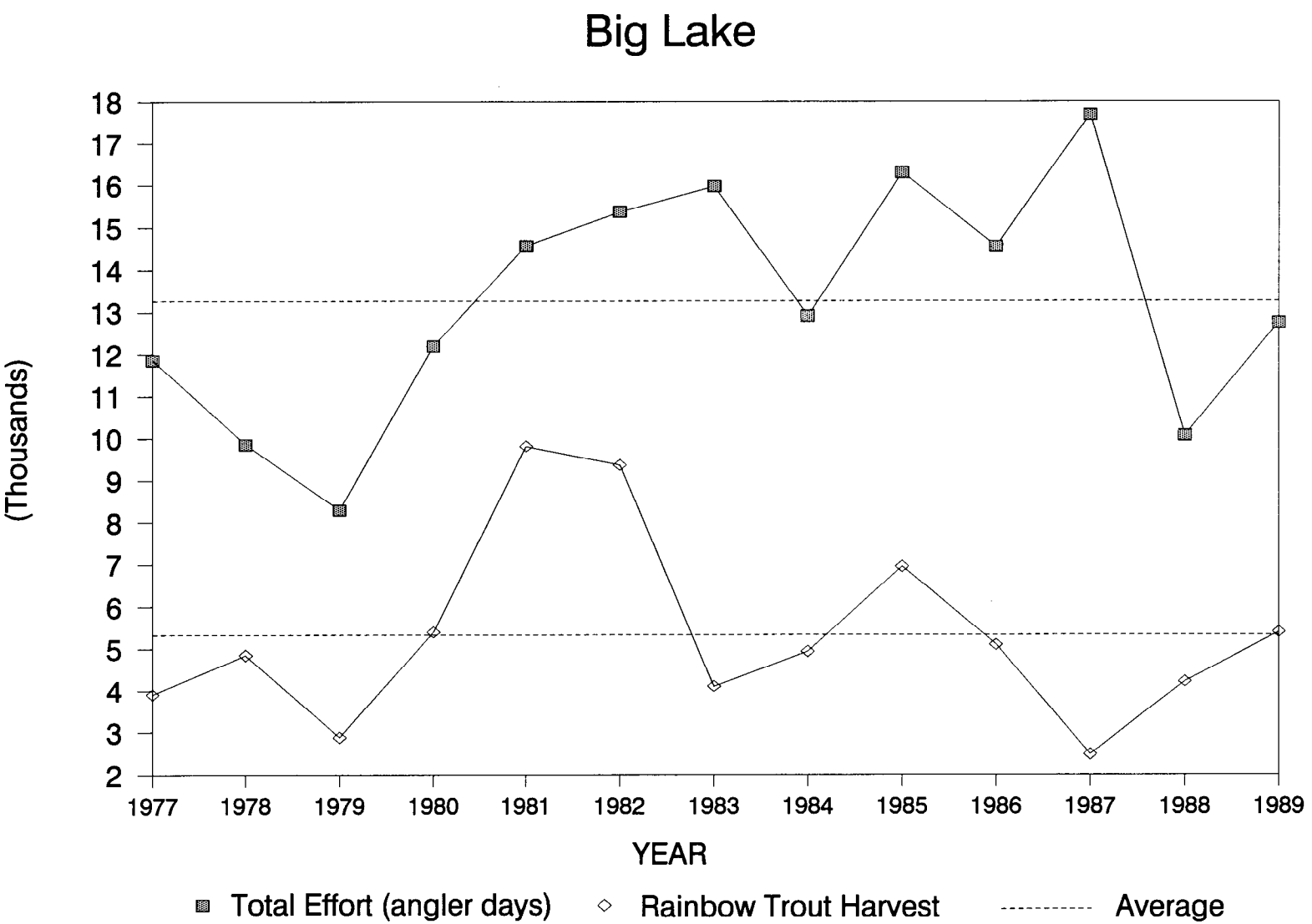

Figure 2. Angler effort and rainbow trout harvest estimates for Big Lake from the statewide postal survey, 1977-1989 (Mills 1979-1990).

Data Collection

Mark-recapture experiments were conducted to estimate the abundance of rainbow trout in Big Lake in the fall of 1989 and 1990. Three samples were taken in each year: two during September and one during early October. Fyke nets were used to capture the fish. These fyke nets were 2.7 m (9 ft) long, 91.4 cm (36 in) in diameter, and had two 0.9 m by 6.1 m (3 ft by 20 ft) wings. Internal throats, body, and wings were of 0.48 cm (3/16 in) square mesh knotless nylon. Net sampling sites were selected around the shores of Big Lake, Mirror Lake, and Flat Lake. The lake complex was stratified into three areas: east, south, and northwest (Figure 1), and catches from each net in each area were recorded separately. In both years, an effort was made to distribute the tagging and recovery effort as evenly as possible around the shores of the lakes. Approximately 160 net sets were made for each sample. Nets were fished for approximately 24 hours then pulled and relocated. Ten to fifteen days were needed to sample the entire lake complex.

All trout over 130 mm were marked with a numbered anchor tag (if not already tagged) and given an upper caudal finclip. Captured fish were examined for a mark (either a caudal or adipose finclip or a numbered anchor tag). In each sample, all rainbow trout in at least one fyke net trap load were measured. If there were less than 150 trout $\geq$ 130 mm in the trap, then a second trap was randomly selected and all the fish in it measured also, and this process continued until at least 150 were measured. During each sample, scales were collected from 500 trout $\geq$ 130 mm and 150 trout $<$ 130 mm to determine age composition.

Data Analysis

Population Estimate:

The total population (N) was estimated by Chapman's modification of the Petersen estimator (Seber 1982):

$$N = \frac{(M+1)(C+1)}{(R+1)}, \qquad [1]$$

with variance:

$$V(N) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \qquad [2]$$

where:

M = number of tagged fish released during the first event,

C = number of fish examined for tags during the second event, and

R = number of tagged fish recaptured during the second event.

The following assumptions were necessary for this procedure:

1. tagged and untagged fish had the same probability of capture;

2. marked fish had the same chance of dying or emigrating as unmarked fish;

3. the population was closed, in that there was no change in the number of fish in the population between events;

4. there was no tag loss; and

5. all fish had the same probability of capture in the marking event or in the recapture event, or marked and unmarked fish mixed completely between marking events.

Mortality. We have no evidence that marking with anchor tags caused behavioral changes or increased mortality that would alter the capture probability of the marked fish (assumptions 1 and 2).

Migration. The nearshore area of the lake is not a closed system. Fish can migrate to and from the offshore area (which we did not sample). However, we felt that this bias would be minimized by confining our sampling to late fall. We had no reason to believe that newly marked fish would move offshore at a different rate than unmarked fish (assumption 2). We also believed that during the turnover of the lake in late fall there would be sufficient movement between the areas of the lake to assure complete mixing of the fish marked nearshore and the unmarked offshore population (assumptions 3 and 5).

Contingency table analyses (Sokal and Rohlf 1969) were used to test for equal mixing of marked and unmarked fish between sampling events and for equal probability of capture of fish from all sublocations during the marking event (assumption 5).

Tag Loss. All tagged fish in 1989 and 1990 were given an upper caudal finclip to allow us to recognize fish that had lost a tag. In the third sample in 1989, one fish which was 205 mm was captured with an upper caudal clip but no tag. This resulted in an estimate of 3.6% tag loss (SE = 3.6). In the third sample in 1990, six fish were captured with upper caudal clips but no tag. None of the six clips showed any regeneration, so all were judged to be clips from 1990. One of the clipped fish was < 130 mm, one was in the range 130-175 mm, and four were > 175 mm. This resulted in an estimate of 2.0% tag loss (SE = 1.6) in the fish 130-175 mm, and 7% tag loss in the fish > 175 mm (SE = 3.5).

Size Selectivity. We used either two-sample Kolmogorov-Smirnov tests (Daniel 1978) or Anderson-Darling tests (Scholz and Stephens 1987) to compare length distributions of all fish ≥ 130 mm released with tags in the first event to the recaptures in the second event. Significance of these comparisons would suggest there was size selectivity (unequal capture probabilities for different size groups) in the sample from the second event (assumption 5). We also compared the length distribution of all fish released with tags in the first

event to all fish captured in the second event. Significance of this comparison would indicate a difference in size distribution between the two events.

Age Composition:

We estimated the proportional age composition of rainbow trout in our samples using:

$$\hat{P}_a = n_a/n \ , \qquad [3]$$

where:

$\hat{P}_a$ = the estimated proportion of age class a,

n_a = the number of fish in age class a in the sample, and

n = the number of scale samples read.

The variance of P_a is equal to:

$$V(\hat{P}_a) = \frac{(\hat{P}_a)(1-\hat{P}_a)}{n} \ . \qquad [4]$$

The number of fish in the total population in each age class could then be estimated by:

$$\hat{N}_a = \hat{P}_a\hat{N} \ , \qquad [5]$$

where:

$\hat{N}_a$ = the number of fish in age class a, and

$\hat{N}$ = the number of fish in the population.

The variance of $\hat{N}_a$ is equal to (Goodman 1960):

$$V(\hat{N}_a) = V(\hat{N})\hat{P}_a^2 + V(\hat{P}_a)\hat{N}^2 - V(\hat{N})V(\hat{P}_a) \ . \qquad [6]$$

Hatchery Contribution:

In 1990, we estimated the number of age-1 fish of hatchery origin in the population, which represent the survivors of the 1989 fingerling stocking. First we determined the number of age-1 fish with adipose clips in the population:

$$\hat{N}_f = \hat{N}\hat{P}_f \ , \qquad [7]$$

where:

$\hat{N}_f$ = the number of age-1 fish with adipose clips in the population,

$\hat{P}_f$ = the estimated proportion of age-1 adipose clipped fish in the population

= (n_f/n) with variance as for $\hat{P}_a$, above,

n_f = the number of age-1 fish with adipose clips in the sample,

n = the number of scale samples read, and

$\hat{N}$ = as defined above.

The variance for N_f is calculated by substituting P_f and $V(P_f)$ into the equation for the variance of N_a, above.

Then the proportion of the stocked fish released with adipose clips in 1989 was used to estimate the total number of surviving stocked age-1 fish in the population.

$$\hat{N}_s = \hat{N}_f/\theta \ , \qquad [8]$$

where:

$\hat{N}_s$ = the number of age-1 stocked fish in the population, and

θ = the proportion of released fingerlings that were clipped.

The variance of N_s is equal to:

$$V(\hat{N}_s) = V(\hat{N}_f)/\theta^2 \ . \qquad [9]$$

1989 RESULTS

In 1989, fingerlings stocked in the early summer of 1989 were all considered to be under 120 mm at sampling, and mostly under 110 mm. The taggable fish were those over 150 mm in 1989. The taggable fish included catchables stocked in 1988 and wild trout.

During 1989, sampling occurred during three events: the first from 12 to 22 September, the second from 26 September to 6 October, and the third from 17 to 26 October. The lake was divided into three strata based on results in 1988 (Havens and Alexandersdottir 1990): the east and south sections, and the northwest section which includes Flat and Mirror Lakes (Figure 1). A total of 2,017 rainbow trout were taken in the three samples; 695 in the east section, 432 in the south, and 890 in the northwest section (Table 1).

Table 1. Distribution of rainbow trout in Big Lake during 1989 sampling.

Sample	Stratum			Total
	East	South	Northwest	
9/12-9/22	178	142	398	718
9/26-10/06	169	131	169	469
10/17-10/26	348	159	323	830
Total	695	432	890	2,017

Finclips in Trout Under 120 mm

In the early summer of 1989, 216,371 fingerlings were released into Big Lake, of which 72,000 or 33% were adipose finclipped. During the fall sampling, the clip ratios differed by size, stratum, and time (Table 2). The ratio for the total sample decreased from 35% to 26% from samples 1 to 3, and ranged from 19% to 41% from the east to the northwest sections (Table 2). Adipose clip ratios also increased with size of fish.

Distribution of Rainbow Trout

Rainbow trout were segregated by area, time, and size (Table 3). In all samples, more small fish were taken in the northwest end of the lake and very few in the east section (Table 3). A total of 553 trout under 150 mm were taken in the northwest section, 64% of the total for the section over all samples, while only 126 were caught in the east end, or 25% of the total. In the south section, 180 trout under 150 mm were taken which was 44% of the total catch in that lake area (Table 3). Temporal trends by size were also evident. In the northwest area, the percentage of trout under 150 mm declined from 86% in the first sample to 60% in the second sample and 37% in the third. This difference in distribution of small fish by time and area was significant.

A comparison of adipose clipped and unclipped trout in the < 120 mm size group shows that for all the fish combined there was a higher proportion of larger fish with clips (Figure 3, $D = 0.16$, $P < 0.05$). However, when the length frequencies of clipped and unclipped fish were compared within sample and strata (Table 4), there were no significant differences. The larger fish, which had higher clip ratios, were found in the northwest section. The smaller fish found in the remaining areas of the lake had lower clip ratios.

Population Estimate

No differences in length distribution for trout over 150 mm were found between samples 1 and 2 for any strata, while samples 2 and 3 were found to be different in all strata and samples 1 and 3 in the northwest stratum (Table 5). Therefore, for the purposes of the population estimate, samples 1 and 2 were combined as the release event (event 1), and the third sample was the recapture event (event 2). A total of 450 rainbow trout ≥ 150 mm were released with tags in event 1 (Table 6). Twenty-seven were recovered in event 2.

Size Selectivity:

A comparison of the length distributions of released fish versus fish recaptured in the second event (Figure 4) was significant when all fish were combined (Table 7), but not significant if the trout were stratified into 2 groups, fish between 150-340 mm and fish over 340 mm. Only two trout larger than 340 mm were recaptured. A comparison of all trout over 150 mm sampled in the two events is significant, whether all sizes are combined or are stratified (Table 7) indicating selectivity in the first event. There is no selectivity on the tagged population within the 150-340 mm group. There were not enough recaptures to test for selectivity in fish over 340 mm.

Table 2. Percent of rainbow trout under 120 mm adipose finclipped in Big Lake sampling, 1989.

Sample	Stratum			Total
	East	South	Northwest	
9/12-9/22	14.3	3.9	43.5	35.0
9/26-10/06	11.1	18.0	44.9	33.8
10/17-10/26	24.1	18.2	30.3	26.5
Total	18.6	11.2	41.5	33.1

Table 3. Distribution of rainbow trout by size class in Big Lake, 1989, showing the numbers smaller than 150 mm and larger than 150 mm, and the percent by sample and stratum.

		Stratum					
		East		South		Northwest	
		≤150	>150	≤150	>150	≤150	>150
9/12-9/26	Number	45	134	88	58	341	56
	Percent	25	75	59	41	86	14
9/26-10/06	Number	31	129	55	65	101	67
	Percent	19	81	46	54	60	40
10/17-10/26	Number	46	125	43	105	111	187
	Percent	27	73	29	71	37	63
Total	Number	126	388	180	228	553	310
	Percent	25	75	44	56	64	34

H_o: Distribution of small (≤ 150 mm) and large (> 150 mm) fish is independent of time and location.

$\chi^2 = 63.67$ df = 4 $P < 0.0001$ Reject H_o

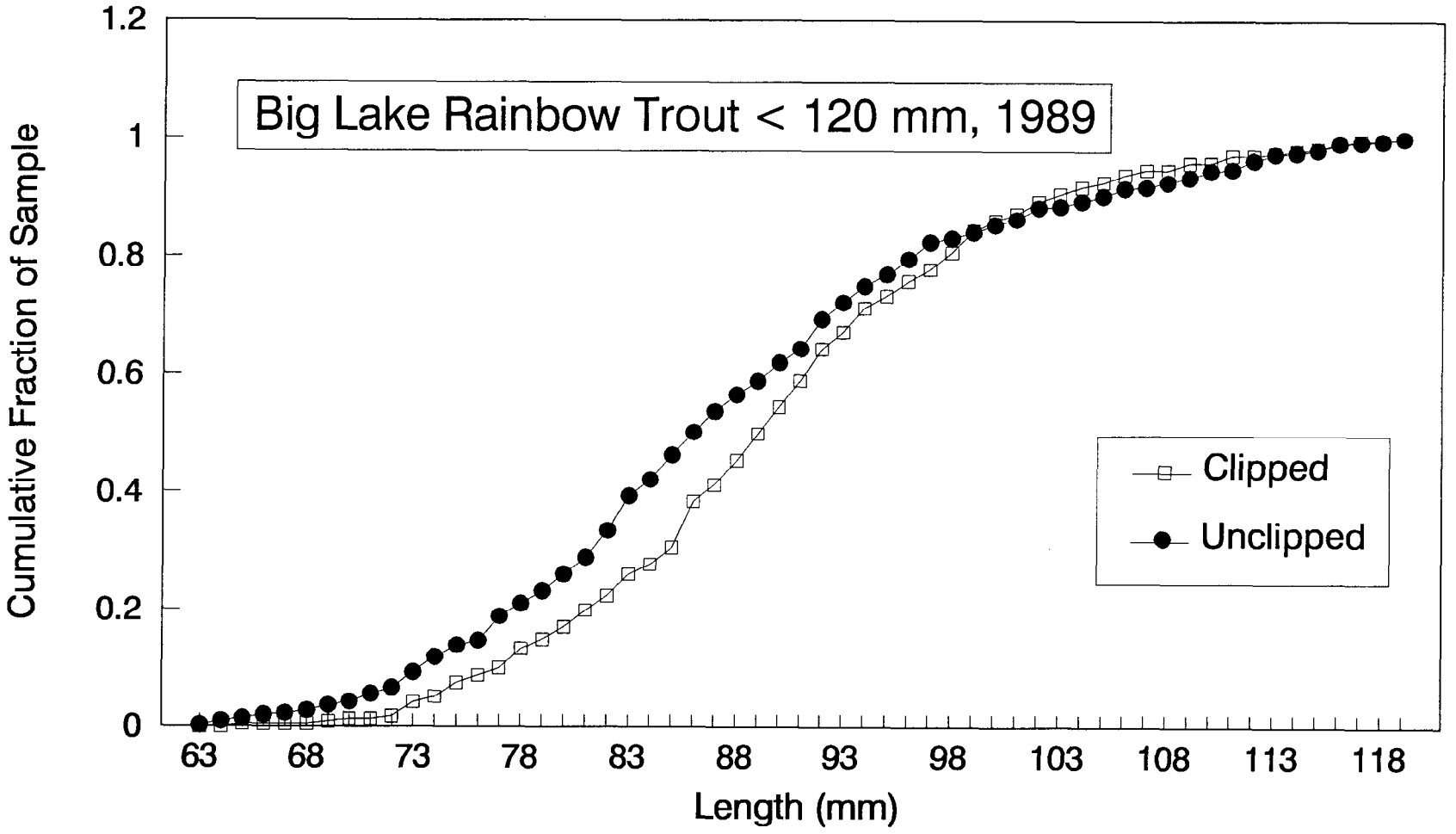

Figure 3. Cumulative length distribution of adipose clipped and unclipped rainbow trout < 120 mm in Big Lake sampling, 1989.

Table 4. Comparison of length distributions of clipped and unclipped rainbow trout under 120 mm in Big Lake sampling, 1989.

Sample	Stratum	Number in Sample		D	P value
		Unclipped	Clipped		
1	East	9	3	0.89	0.057
	South	68	3	0.47	0.534
	Northwest	180	144	0.14	0.103
2	East	6	1	0.67	0.841
	South	35	9	0.32	0.453
	Northwest	41	50	0.13	0.802
3	East	13	5	0.49	0.346
	South	20	4	0.35	0.809
	Northwest	49	23	0.17	0.771

Table 5. Results of Kolmogorov-Smirnov tests comparing length distributions for rainbow trout over 150 mm sampled in Big Lake in 1989.

	P values[a]		
Between samples:	1 and 2	1 and 3	2 and 3
East Stratum	0.11	0.25	0.003 *
South Stratum	0.59	0.62	0.01 *
Northwest Stratum	0.69	0.005 *	0.0001 *
Between strata:[b]	E and S	E and NW	S and NW
Sample 1	0.82	0.41	0.76
Sample 2	0.75	0.88	0.82
Sample 3	0.32	0.006 *	0.27

[a] A p-value less than 0.05 is significant. An * indicates a significant difference between the two length distributions at $\alpha = 0.05$.

[b] Strata: E = East, S = South, NW = Northwest

Table 6. Number of rainbow trout recovered by release and recovery strata in Big Lake, 1989.

Release Stratum	Recovery Stratum			Total Release	Recovered		Not Recovered
	East	South	Northwest		Total	Percent	
East	7	3	2	241	12	4.9	229
South	0	0	4	112	4	3.6	108
Northwest	0	2	9	97	11	11.3	86
Recovered	7	5	15				
Examined	131	101	176				
Unmarked	124	96	161				
Percent Marked	5.3	4.9	8.5				

H_o: There is no difference in percent recovered by release strata.

$\chi^2 = 6.52$ df = 2 $0.005 < P < 0.10$ Reject H_o

H_o: There is no difference in percent marked by recovery strata.

$\chi^2 = 1.83$ df = 2 $0.25 < P < 0.50$ Accept H_o

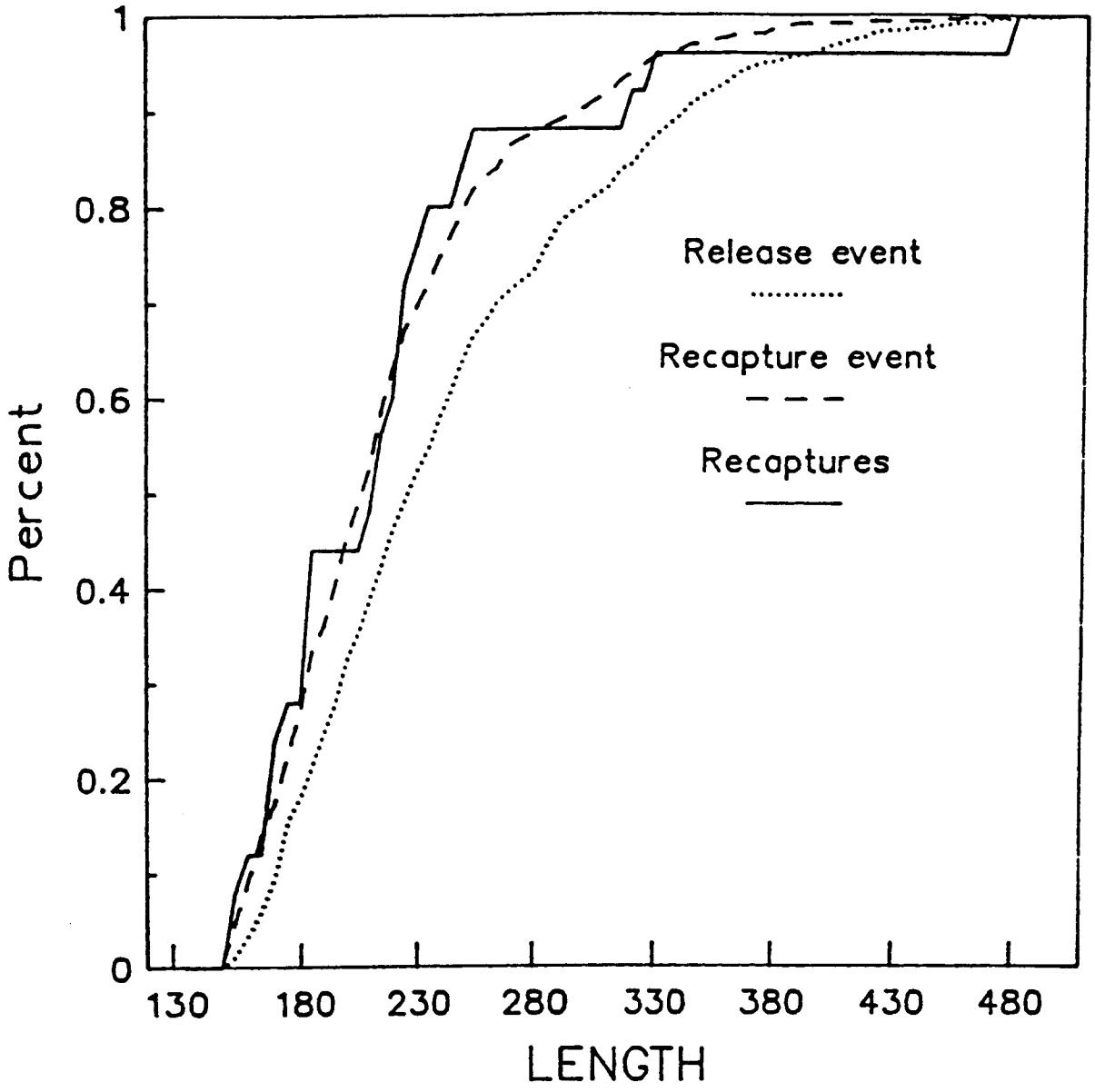

Figure 4. Cumulative length distributions of rainbow trout sampled during release and recapture event and captured for a second time in Big Lake mark-recapture experiment 1989.

Table 7. Results of Anderson-Darling tests comparing length distributions of release and recaptured rainbow trout in Big Lake, 1989.

	Sample Sizes by Event			
	1[a]	2[b]	T_{akn}	P value
All fish:				
Event 1 vs. Event 2	498	460	24.7	<0.001
Release vs 2nd Capture	498	27	2.45	<0.05
Fish 150-340 mm:				
Event 1 vs. Event 2	444	442	14.68	<0.001
Release vs 2nd Capture	444	25	1.6	>0.1 (ns)

[a] Release event which consists of sampling events 1 (9/12/89-9/22/89) and 2 (9/26/89-10/6/89).

[b] Recapture event which consists of sampling event 3 (10/17/89-10/26/89).

We concluded that, for the purposes of population estimation, we needed to stratify the rainbow trout into two size groups. For estimates of length and age composition of the population, only samples taken during the second event (third sample) would be used.

Probability of Capture:

Although the comparison of the proportion recovered by release strata was significant at an alpha level of 0.05 (Table 6), the comparison of percent marked by recovery strata was not significant at these sample sizes (Table 6). Therefore, the population abundance could be estimated using the Petersen estimator.

Population Estimate:

The estimate is 7,094 trout between the sizes 150-340 mm and 1,097 over 340 mm, for a total of 8,191 rainbow trout over 150 mm in Big Lake in 1989. The relative precision of the 95% confidence interval is 28% for the total abundance estimate (Table 8). This estimate of abundance is a dramatic decrease from the October 1988 estimate of over 22,000 wild fish and 24,033 released catchables (Havens and Alexandersdottir 1990).

Age Composition

During the third sample (17 October to 26 October), 279 rainbow trout were sampled for age. The mean length for age-1 rainbow trout in October 1989 was 184 mm (SE = 2) (Table 9). In the group < 150 mm, 43% were age 1. In the total sample, 68.8% were age 1 (Table 10). Seventy-seven percent of the fish in the range 150-340 mm were age 1 and none in the sample over 340 mm were age 1. The estimated number of age-1 rainbow trout ≥ 150 mm in the population in 1989 (Table 11) is 5,452 (SE = 1,008). The estimated number of age-2 fish ≥ 150 mm is 1,616 (SE = 266).

1990 RESULTS

In 1990, three samples were taken, the first from 5 September through 13 September, the second from 18 September through 28 September, and the third from 2 October through 12 October. The lake was divided into the same three strata as in 1989 (Figure 1). A total of 3,536 rainbow trout were captured in the three samples: 1,324 in the east strata, 712 in the south strata, and 1,500 in the northwest strata (Table 12).

Finclips in Trout Under 130 mm

In 1990, 449,627 rainbow trout fingerlings were released into Big Lake, of which 76,869 (17.1%) had been given adipose finclips. During the fall sampling, the percentages of fish < 130 mm with adipose clips across all strata ranged from 16.7% to 17.4% (Table 13) and were not significantly different among samples in any strata. The percentages with adipose clips among strata during sample 1 and sample 2 were also not significantly different (Table 13). As in 1989, in all samples the percentage with adipose clips

Table 8. Estimate of population abundance for rainbow trout larger than 150 mm in Big Lake in 1989.

Size group	Released	Examined	Recaptured	Abundance	SE	Relative Precision[a]
150-340 mm	450	408	25	7,094	1,287	36%
>340 mm	60	53	2	1,097	525	94%
Total				8,191	1,390	33%

[a] Relative precision at $\alpha = 0.05$ expressed as a percentage of the abundance estimate.

Table 9. Mean length (millimeters fork length) at age for Big Lake rainbow trout, 1989.

	Age						
Year	0	1	2	3	4	5	Total
Mean Length	115	184	256	330	387	460	
SE	3.8	1.9	5.8	7.3	13.7		
Sample Size	21	192	47	11	7	1	279
Minimum	87	122	195	304	331	460	
Maximum	148	245	357	376	446	460	

Table 10. Age composition of Big Lake rainbow trout sampled 17 October to 26 October 1989.

	Age						
	0	1	2	3	4	5	Total
Length < 150 mm							
Number	21	16	0	0	0	0	37
% of Sample	56.8	43.2					100.0
SE	8.26	8.26					
Length 150-340 mm							
Number	0	176	44	8	1	0	229
% of Sample		76.9	19.2	3.5	0.4		100.0
SE		2.79	2.61	1.22	0.44		
Length > 340 mm							
Number	0	0	3	3	6	1	13
% of Sample			23.1	23.1	46.2	7.7	100.0
SE			12.16	12.16	14.39	7.69	
Total							
Number	21	192	47	11	7	1	279
% of Sample	7.5	68.8	16.8	3.9	2.5	0.4	100.0
SE	1.58	2.78	2.24	1.17	0.94	0.36	

Table 11. Rainbow trout population estimate by age, 1989.

	Age					
	0	1	2	3	4	5
Length 150-340 mm						
Proportion in Sample (P_a)	0.000	0.769	0.192	0.035	0.004	0.000
$V(P_a)$		0.000777	0.000678	0.000147	0.000019	0.000000
Estimated Number (N_a)	0	5,452	1,363	248	31	0
$V(N_a)$		1,016,192	60,027	403,916,796	0	0
Length > 340						
Proportion in Sample (P_a)	0.000	0.000	0.231	0.231	0.462	0.077
$V(P_a)$			0.013655	0.013655	0.019117	0.005462
Estimated number (N_a)	0	0	253	253	506	84
$V(N_a)$			10,915	1,037,368,320	53,444	125
Total						
Estimated Number (N_a)	0	5,452	1,616	501	537	84
$V(N_a)$	0	1,016,192	70,941	1,441,285,115	53,444	125
SE	0	1,008	266	37,964	231	11

Table 12. Distribution of rainbow trout in Big Lake during 1990 sampling.

Sample	Stratum			Total
	East	South	Northwest	
9/15-9/13	392	207	518	1,117
9/18-9/28	516	305	507	1,328
10/2-10/12	416	200	475	1,091
Total	1,324	712	1,500	3,536

Table 13. Percent of captured rainbow trout under 130 mm with adipose finclips in each Big Lake sampling event, 1990.

Sample	Stratum			Total
	East	South	Northwest	
9/5-9/13	13.3	13.7	19.1	16.7
9/18-9/28	12.9	15.2	19.9	17.4
10/2-10/12	14.5	4.4	20.2	16.8

H_o: The percentage of fish with adipose clips is the same among samples.

East:	$\chi^2_2 = 0.92$	df = 2	$0.95 < P < 0.975$	Accept H_o
South:	$\chi^2_2 = 3.63$	df = 2	$0.10 < P < 0.25$	Accept H_o
Northwest:	$\chi^2 = 0.11$	df = 2	$0.50 < P < 0.75$	Accept H_o

H_o: The percentage of fish with adipose clips is the same among strata.

9/5-9/13	$\chi^2_2 = 3.03$	df = 2	$0.10 < P < 0.25$	Accept H_o
9/18-9/28	$\chi^2_2 = 3.42$	df = 2	$0.10 < P < 0.25$	Accept H_o
10/2-10/12	$\chi^2 = 6.83$	df = 2	$0.025 < P < 0.05$	Reject H_o

was higher in the northwest strata than in the east or south, but this difference was not significant in sample 1 or sample 2 (Table 13). In sample 3, the percentage with adipose clips was significantly different between strata. Relatively few small fish with adipose clips were captured in the south strata in sample 3.

Distribution of Rainbow Trout

As in 1989, the rainbow trout were segregated by size class. Proportionally more small fish (< 130 mm) were taken from the northwest strata and few in the east strata during all samples (Tables 14 and 15).

The distribution by size class also changed over time in each strata, with more large (> 175 mm) fish taken from all strata during the last sample. These differences in distribution were significant (Tables 14 and 15). However, there was not a significant difference between the length distributions from samples 1 and 2 for fish 130-175 mm or for fish > 175 mm in any strata (Table 15). Because the length distributions were not different for samples 1 and 2 for fish > 130 mm, these two samples were combined into one event for the population estimate.

Population Estimate

For the population estimate, samples 1 and 2 were combined as the release event (event 1), and the third sample was the recapture event (event 2). A total of 1,221 rainbow trout ≥ 130 mm were released with tags in event 1. Some fish < 130 mm were also tagged, but tagging was not done consistently for these fish so they were not included in the population estimate.

Size Selectivity:

To test for gear selectivity, the length distribution of all fish ≥ 130 mm released in the first event was compared to the distribution of all fish ≥ 130 mm captured in the second event using a two sample Kolmogorov-Smirnov test. The two distributions were significantly different at $\alpha = 0.05$ (Table 16, Figure 5). However, the length distribution of the fish released in event 1 was not significantly different from the length distribution of the tagged recaptures in event 2 (Table 16, Figure 5). This test indicates that there was no size selectivity in the second event, but since the distribution from the first event is not the same as that from the second, there must have been selectivity in the first event. Because there was no selectivity on the tagged population in the second event, it is not necessary to break the population estimate into separate length classes, however we chose to estimate the population size for two length classes (130-175 mm and > 175 mm) because of the results of the tests for equal probability of capture by sublocation which follow. The sample of lengths and ages from the second event is representative of the estimated population, but the sample from the first event probably is not.

Probability of Capture by Sublocation:

The proportion of tagged recoveries by release strata (the east, south and northwest sublocations) was significantly different for all lengths combined

Table 14. Distribution of rainbow trout by size class in Big Lake in 1990, showing the percent in each size class by sample and stratum.

	Stratum								
	East			South			Northwest		
Sample	<130	130-175	>175	<130	130-175	>175	<130	130-175	>175
9/5-9/13									
Number	113	145	134	117	62	28	314	148	56
Percent	29	37	34	57	30	14	61	29	11
9/18-9/28									
Number	101	212	203	171	54	80	327	116	64
Percent	20	41	39	56	18	26	64	23	13
10/2-10/12									
Number	62	102	252	45	59	96	203	133	139
Percent	15	25	61	23	29	48	43	28	29

H_o: The distribution of small (< 130 mm) and large (≥ 130 mm) rainbow trout is independent of time and area.

$\chi^2 = 10.35$ df = 4 P = 0.035 Reject H_o

Table 15. Results of Anderson-Darling tests comparing length distributions for rainbow trout sampled in Big Lake in 1990, by size group.

	T_{akN} [a]		
Fish ≥ 130 mm and ≤ 175 mm			
Between Samples:	1 and 2	1 and 3	2 and 3
East Stratum	1.122	2.360 *	-0.504
South Stratum	-0.343	-0.449	0.277
Northwest Stratum	0.487	7.611 *	1.485
Between Strata:[b]	E and S	E and NW	S and NW
Sample 1	2.691 *	-0.851	2.349 *
Sample 2	-0.559	-0.039	0.455
Sample 3	61.992 *	1.621	90.975 *
Fish > 175			
Between Samples:	1 and 2	1 and 3	2 and 3
East Stratum	-0.396	3.130 *	4.019 *
South Stratum	0.494	41.184 *	0.262
Northwest Stratum	-0.017	2.238 *	7.797 *
Between Strata:[b]	E and S	E and NW	S and NW
Sample 1	-0.276	1.186	-0.440
Sample 2	3.030 *	3.016 *	6.295 *
Sample 3	1.768	-0.021	1.035

[a] An * indicates a significant value of T_{akN} at $\alpha = 0.05$.

[b] Strata: E = East, S = South, NW = Northwest

Table 16. Comparison of length distributions of rainbow trout from release and recapture events of population estimate in Big Lake, 1990.

	Sample Sizes by Event		Kolmogorov-Smirnov test	
	1[a]	2[b]	D [c]	Critical D at α = 0.05
All fish ≥ 130 mm:				
Event 1 vs. event 2	1,221	753	0.2009 *	0.0630
Release vs. recapture	1,221	114	0.0923	0.1332
Fish 130-175 mm:				
Event 1 vs. event 2	683	281	0.0885	0.0964
Release vs. recapture	683	63	0.1595	0.1791
Fish > 175 mm:				
Event 1 vs. event 2	538	472	0.1046 *	0.0858
Release vs. recapture	538	51	0.1162	0.1993

[a] Release event which consists of sampling events 1 (9/5/90-9/13/90) and 2 (9/18/90-9/28/90).

[b] Recapture event which consists of sampling event 3 (10/2/90-10/12/90).

[c] An * indicates a significant difference between the two length distributions at α = 0.05.

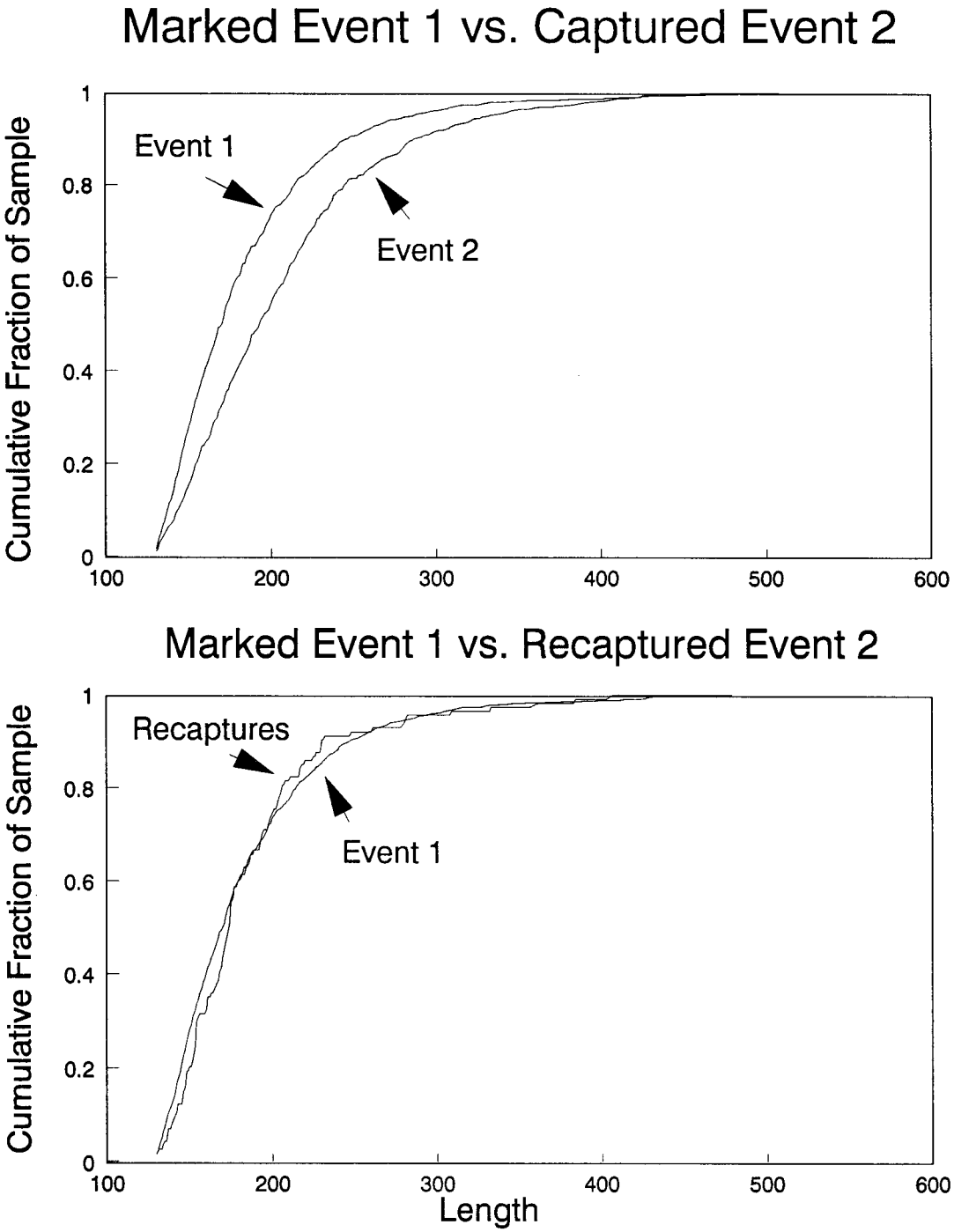

Figure 5. Cumulative length distribution of rainbow trout released in event 1 compared to rainbow trout captured in event 2, and of rainbow trout released in event 1 compared to recaptures in event 2, 1990.

and also was significantly different for fish 130-175 mm (Table 17) and for fish > 175 mm (Table 18).

The percent marked by recovery strata was significantly different for all lengths combined but was not significantly different when the fish were broken into the two length classes (Tables 17 and 18). Therefore, for the two size classes, a Petersen estimator could be used.

Population Estimate:

The abundance estimate for Big Lake rainbow trout 130-175 mm in 1990 is 2,968; and for rainbow trout > 175 mm is 4,562, for a total of 7,530 rainbow trout ≥ 130 mm with the relative precision of the 95% confidence interval at 16% (Table 19). This is similar to the 1989 estimate of 8,191 rainbow trout ≥ 150 mm.

Age Composition

In event 2 (sample 3), 721 rainbow trout were aged. The mean length for age-1 rainbow trout in October 1990 was 182 mm (SE = 2) (Table 20). All of the fish from 130 to 175 mm were age 1 (Table 21). Seventy percent of the fish > 175 mm were age 1. The estimated number of age-1 rainbow trout > 130 mm in the population in 1990 (Table 22) is 6,143 (SE = 495). The estimated number of age-2 fish > 130 mm is 625 (SE = 112).

Hatchery Contribution

Age-1 rainbow trout in 1990 consisted of wild fish plus the survivors of the 216,371 hatchery fingerlings that were stocked in 1989. Thirty-three percent of the hatchery fingerlings stocked in 1989 were given adipose finclips. Sixty of the age-1 fish ≥ 130 mm sampled in 1990 had adipose finclips: 24 in the 130-175 mm length group and 36 in the > 175 mm length group. The percent with adipose finclips in these two length groups results in an estimate of 2,603 stocked fish in the age-1 population ≥ 130 mm in 1990 (Table 23).

There were also age-1 fish that were < 130 mm (Table 21). In the age sample, 29 of the 455 age-1 fish were < 130 mm, and 8 of those 29 had adipose finclips. Therefore, 6.4% of the sample of age-1 fish were < 130 mm. If we assume no sampling bias on smaller fish, and this percentage is added to the population estimate of 6,143 age-1 fish ≥ 130 mm (Table 22), then the estimate of the number of age-1 fish in the entire population (Table 24) increases to 6,535 (SE = 502). The estimate of the number of age-1 stocked fish increases by 21 to 2,624 (SE = 378). The estimated survival of the fingerlings from the 1989 stocking to the fall of 1990 is therefore only 1.2% (Table 25). Survivals estimated from 1989 to 1990 are 12% for age 1, 31% for age 2, 37% for age 3, and 15% for age 4.

DISCUSSION

For both 1989 and 1990, the abundance estimates for rainbow trout in Big Lake are surprisingly low. The estimate of the total number of rainbow trout age 2 and older in 1989 was only 2,738 fish. In 1988, 24,033 catchable rainbow

Table 17. Number of tagged rainbow trout 130-175 mm recovered by release and recovery strata in Big Lake, 1990.

Release Stratum	Recovery Stratum			Total Release	Recovered		Not Recovered
	East	South	Northwest		Total	Percent	
East	11	1	1	336	13	3.9	323
South	6	5	2	106	13	12.3	93
Northwest	0	8	29	241	37	15.4	204
Recovered	17	14	32				
Examined	98	58	125				
Unmarked	81	44	93				
Percent Marked	17.3	24.1	25.6				

H_o: There is no difference in percent recovered by release strata.

$\chi^2 = 23.488$ df = 2 $P < 0.001$ Reject H_o

H_o: There is no difference in percent marked by recovery strata.

$\chi^2 = 2.275$ df = 2 $0.25 < P < 0.50$ Accept H_o

Table 18. Number of tagged rainbow trout > 175 mm recovered by release and recovery strata in Big Lake, 1990.

Release Stratum	Recovery Stratum			Total Release	Recovered		Not Recovered
	East	South	Northwest		Total	Percent	
East	16	3	3	325	22	6.8	303
South	3	2	2	102	7	6.9	95
Northwest	6	3	13	111	22	19.8	89
Recovered	25	8	18				
Examined	249	90	134				
Unmarked	224	82	116				
Percent Marked	10.0	8.9	13.4				

H_o: There is no difference in percent recovered by release strata.

$\chi^2 = 17.427$ df = 2 $P < 0.001$ Reject H_o

H_o: There is no difference in percent marked by recovery strata.

$\chi^2 = 1.4571$ df = 2 $0.25 < P < 0.50$ Accept H_o

Table 19. Estimate of population abundance for rainbow trout larger than 129 mm in Big Lake in 1990.

Size Group (mm)	Released	Examined	Recaptured	Estimated Abundance	Standard Error	Relative Precision[a]
130-175	683	281	64	2,968	305	20%
> 175	538	473	55	4,562	537	23%
Total				7,530	618	16%

[a] Relative precision of 95% confidence interval.

Table 20. Mean length at age for Big Lake rainbow trout, 1990.

	Age						
Year	0	1	2	3	4	5	Total
Mean Length	84	182	267	332	386	469	
SE	1.0	1.8	3.4	6.7	7.8	11.8	
Sample Size	162	455	47	37	24	6	721
Minimum	59	109	212	278	310	422	
Maximum	122	282	315	446	426	507	

Table 21. Age composition of Big Lake rainbow trout sampled 2 October to 12 October 1990.

	Age						
	0	1	2	3	4	5	TOTAL
Length < 130 mm							
Number Sampled	162	29	0	0	0	0	191
% of Sample	84.8	15.2					100.0
SE	2.60	2.60					
Length 130-175 mm							
Number Sampled	0	188	0	0	0	0	188
% of Sample		100.0					100.0
SE		0.00					
Length > 175 mm							
Number Sampled	0	238	47	37	14	6	342
% of Sample		69.6	13.7	10.8	4.1	1.8	100.0
SE		2.49	1.86	1.68	1.07	0.71	
Total							
Number Sampled	162	455	47	37	14	6	721
% of Sample	22.5	63.1	6.5	5.1	1.9	0.8	100.0
SE	1.56	1.80	0.92	0.82	0.51	0.34	

Table 22. Rainbow trout population estimate by age, 1990.

	Age					
	0	1	2	3	4	5
Length 130-175 mm						
Proportion in Sample (P_a)	0.000	1.000	0.000	0.000	0.000	0.000
$V(P_a)$		0				
Estimated Number (N_a)	0	2,968	0	0	0	0
$V(N_a)$		92,915				
Length > 175 mm						
Proportion in Sample (P_a)	0.000	0.696	0.137	0.108	0.041	0.018
$V(P_a)$		0.000619	0.000346	0.000282	0.000115	0.000052
Estimated Number (N_a)	0	3,175	625	493	187	82
$V(N_a)$		152,481	12,511	9,147	2,845	1,154
Total						
Estimated Number (N_a)	0	6,143	625	493	187	82
$V(N_a)$		245,396	12,511	9,147	2,845	1,154
SE		495	112	96	53	34

Table 23. Estimate of the number of age-1 stocked fish ≥ 130 mm, 1990.

	Length		
	130-175	> 175	Total
Population Estimate (N)	2,968	4,562	
V(N)	92,915	288,562	
Total Aged (n)	188	342	
Number Age 1 with Finclips in Sample (n_f)	24	36	
Proportion Age 1 with Finclips in Sample (P_f)	0.128	0.105	
$V(P_f)$	0.00059	0.00028	
Estimated No. Age 1 with Finclips (N_f)	379	480	859
SE (N_f)	82	94	125
Number Released in 1988			216,371
Number Released with Finclips			72,000
Proportion Released with Finclips (θ)			0.33
Estimated No. Age-1 Stocked Fish ≥ 130 mm in 1990 (N_s)			2,603
SE (N_s)			378
Relative Precision 95% Confidence Interval			28%

Table 24. Estimate of the number of age-1 fish < 130 mm and the number of age-1 stocked fish < 130 mm in the population, 1990.

Population Estimate age 1 > 130 mm (N_a)	6,143
$V(N_a)$	245,396
Total age 1 in sample (n_a)	455
Number age 1 < 130 mm in sample (n_{a1})	29
Proportion age 1 < 130 mm in sample (P_{a1})	0.06374
$V(P_{a1})$	0.000131
Estimated number age 1 < 130 mm (N_{a1})	391
$V(N_{a1})$	5,914
Estimated total Age 1 (N_{at})	6,535
$V(N_{at})$	251,931
$SE(N_{at})$	502
Number age 1 < 130 mm with finclips in sample (n_{a1s})	8
Proportion age 1 < 130 mm with finclips in sample (P_{a1s})	0.017582
$V(P_{a1s})$	0.000038
Estimated number age 1 < 130 mm with finclips (N_{a1sf})	7
$V(N_{a1sf})$	7
Proportion released with Finclips (θ)	0.33
Estimated number age 1 stocked fish < 130 mm in 1990 (N_{a1s})	21
$V(N_{a1s})$	68
$SE(N_{a1s})$	8
Relative Precision 95% Confidence Interval	78%

Table 25. Summary of Big Lake rainbow trout stocking and population estimates, 1988-1990.

Year	Number and Type Stocked	Population Estimate by Age									
		1									
		Wild	Hatchery	Total	2	3	4	5	Total	Rel.Pre.[a]	
1988	24,033 catchables										
June		na	24,033	na[b]	na	na	na	na	34,640	all fish	12 %
October		na	24,033	na	na	na	na	na	46,294	all fish	23 %
1989	216,371 fingerlings	5,452	0	5,452	1,616	501	537	84	8,190	≥150 mm	28 %
1990	449,627 fingerlings	3,540	2,603	6,143	625	493	187	82	7,530	≥130 mm	16 %
% survival 1989 - 1990			1.2[c]		11.5[d]	30.5[d]	37.3[d]	15.3[d]			

[a] Relative precision at $\alpha = 0.05$.

[b] na = not available.

[c] Survival from spring 1989 stocking to fall 1990.

[d] Survival from fall 1989 to fall 1990.

trout had been stocked and at least 10,000 wild fish were estimated to be present (Table 25). In 1989, 216,371 fingerlings were stocked in Big Lake, but in 1990 we estimated there were only 2,603 surviving age-1 stocked fish ≥ 130 mm and only 6,143 total age-1 fish ≥ 130 mm in the lake. Even if the number of age-1 fish under 130 mm is estimated, the total number of age-1 fish only increases to 6,535 and stocked age-1 fish to 2,624.

There may have been problems with the 1989 fingerling stocking. The ratio of marked to unmarked fish in 1989 increased as the season progressed, and there was a higher proportion of marks among large trout than among small ones. This could be explained if relatively large fingerlings had a higher chance of being marked at the hatchery, and the large fingerlings had a better survival rate than their smaller companions. If this is true, then the marks are not equally distributed in the population, and their survival rate is not representative of all the fish. If the survival rate of the marked fish is higher than that of the rest of the stocked fish, then we would find a disproportionate number of marks in our samples and the estimate of the number of age-1 stocked fish would be biased low. However, this would not affect the estimate of the total population, and even that estimate in 1990 is very low. In addition, the survival estimate for age 1 in 1989 to age 2 is very low; only 12% compared to 30% and 40% for fish at age 2 and age 3 in 1989. In 1988, at least 24,033 age-1 hatchery fish were present in the lake and some unknown number of age-1 wild fish. Yet in 1989, only 1,616 age-2 fish were estimated.

We are faced with two possibilities. Either our population estimates are incorrect; or the abundance of rainbow trout is, in fact, very low. The most obvious potential source of bias in our population estimates is that our sampling is confined to the shores of the lake. If there is an offshore population that does not completely mix with the shoreline population, then our estimates will not represent the entire population. We know that there are rainbow trout in the offshore portions of the lake. In June of 1988, sinking variable-mesh gill nets were set in offshore areas of the lake. These nets were set for a total of 437 net-hours and caught a total of 366 rainbow trout (Havens and Alexandersdottir 1990). The population estimate done in June of the number of wild rainbow trout in the lake in June of 1988 was roughly half of the estimate of the same population done in October of 1988. This difference was attributed to increased mixing due to onshore and offshore movements in the late fall. In 1989 and 1990, only the shoreline areas of the lake were sampled because we assumed that the mixing between the nearshore and offshore populations would be sufficient during the fall turnover to give us accurate estimates of the entire population. This may not be the case.

In 1991 we plan to continue our nearshore sampling, and to use gill nets to sample the offshore population in the second event of the population estimate. This will allow us to test for mixing between the nearshore and offshore populations, and estimate age compositions of near and offshore rainbow trout, and so improve our understanding of the status of the Big Lake rainbow trout populations.

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APPENDIX A

Data Files

Appendix A1. Data files used to produce this report.

K012ALA9.DTA - Lengths, ages, finclips, and tag numbers from sample 1, 1989.

K012ALB9.DTA - Lengths, ages, finclips, and tag numbers from sample 2, 1989.

K012ALC9.DTA - Lengths, ages, finclips, and tag numbers from sample 3, 1989.

K0120LA0.DTA - Lengths, ages, finclips, and tag numbers from sample 1, 1990.

K0120LB0.DTA - Lengths, finclips, and tag numbers from sample 2, 1990.

K0120LC0.DTA - Lengths, ages, finclips, and tag numbers from sample 3, 1990.

These data files are all archived with Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services Unit, 333 Raspberry Road, Anchorage, Alaska 99518-1599. Contact Gail Heineman or Donna Buchholz (267-2369) for copies of the files and descriptions of the file formats.