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SOCKEYE SALMON SMOLT STUDIES
KASILOF RIVER, ALASKA 1982

by
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ABSTRACT

The estimated number of sockeye salmon (Oncorhynchus nerka) smolts emigrating from Tustumena Lake in 1982 was 5.14 million. Of these, an estimated 4.1 million (80%) were age 1.0, and 1.0 million (20%) were age 2.0. The estimated sockeye salmon smolt biomass produced from the lake was 17.1 x 10^3 kg.

The weighted mean lengths, weights, and ages of migrating sockeye salmon smolts were determined from randomly selected samples. The mean length of age 1.0 smolts was 69 mm and the mean weight was 2.9 g. Age 2.0 smolts averaged 82 mm in length and 4.8 g in weight.

Sockeye salmon smolts captured in the Kasilof River were examined for missing ventral fins, which represented hatchery-released fish. During the migration, 55,673 smolts were examined, and 506 marked fish were recovered. The estimated survival rate of marked hatchery fry to age 1.0 smolts was 9.98%. The estimated hatchery contribution to the total smolt outmigration was 892,000 or 17.4%.

Key words: sockeye salmon smolts, (Oncorhynchus nerka), Tustumena Lake, Kasilof River, fan traps, migration estimate, mark and recapture, fin clipped fish, survival rate, and hatchery contribution.

INTRODUCTION

Studies were conducted on the Kasilof River in 1980 and 1981 to obtain information on the sockeye salmon (Oncorhynchus nerka) smolt emigration from Tustumena Lake and to assess the survival and contribution of hatchery-stocked sockeye salmon fry to the total outmigration (Todd et al 1981; Flagg 1982). Hatchery-reared sockeye salmon fry have been released into Tustumena Lake every year since 1976 except for 1977 (Appendix A). The stocking was performed by the Fisheries Rehabilitation, Enhancement, and Development Division (FRED) of the Alaska Department of Fish and Game (ADF&G) in an attempt to enhance sockeye salmon production in the system. This report presents the results of the 1982 smolt project on the Kasilof River, including evaluation of the survival of sockeye salmon fry (released into Tustumena Lake in 1980) to age 1.0 smolts.

The study site is located on the Kasilof River approximately 7 km upstream from Cook Inlet and 16 km upstream from the confluence of Crooked Creek with the Kasilof River (Figure 1). The Kasilof River drains Tustumena Lake, which is turbid with glacial flour. It is an important sockeye salmon nursery lake with a surface area of 29,100 ha. The 1975 - 1981 average estimated annual adult sockeye salmon return (catch plus escapement) attributed to Tustumena Lake wild stocks was 481,000. Average escapement to the lake during this period was 147,000 (Tarbox, et al 1982).

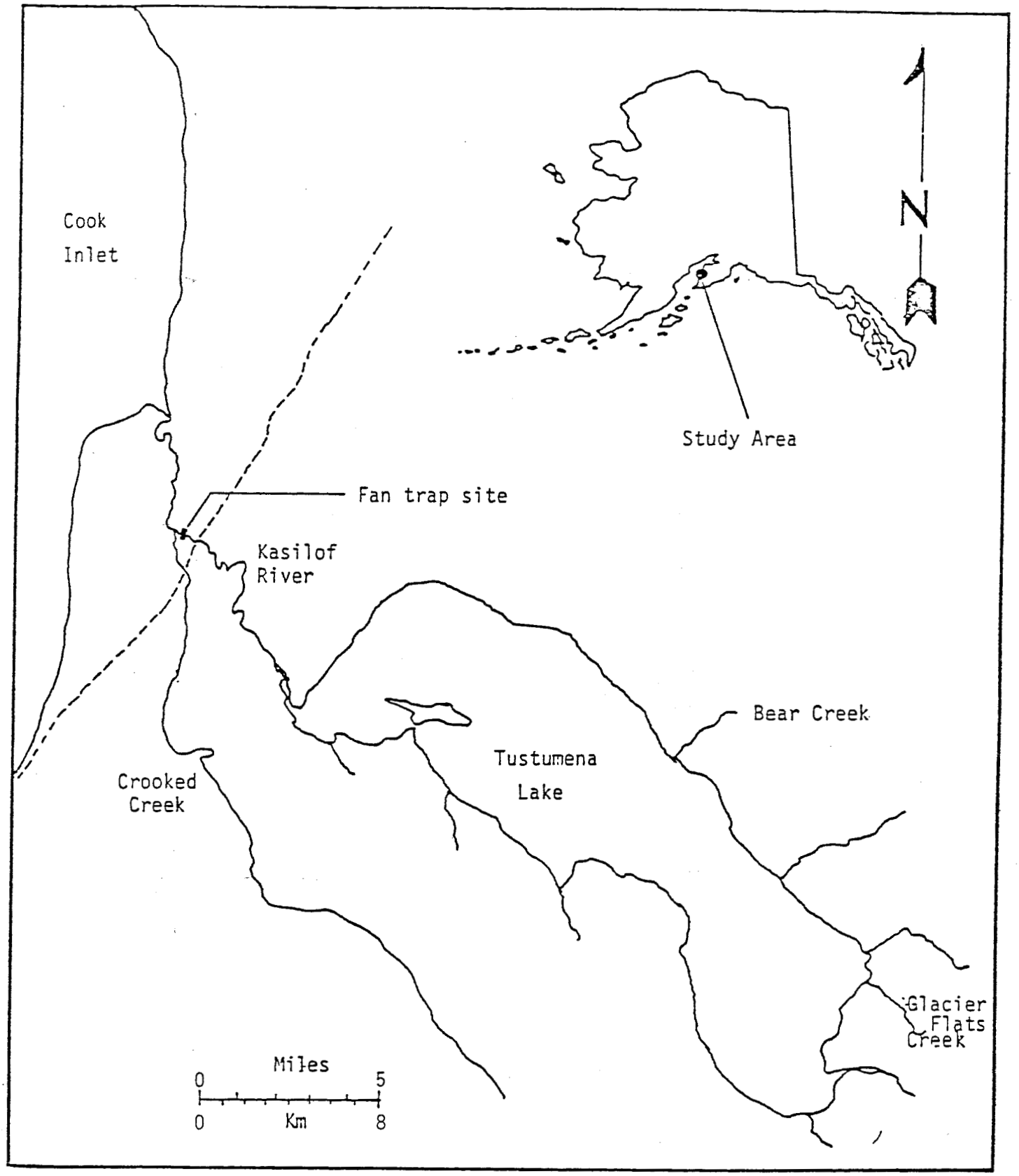

Figure 1. Map showing the relative location of Tustumena Lake, Kasilof River and Crooked Creek.

The objectives of this project were:

1. to determine the timing and magnitude of the sockeye salmon outmigration;

2. to assess the survival rate to smolt of hatchery reared sockeye salmon fry and their contribution to the total smolt migration; and

3. to determine the age structure and the average weight, and length of the migrating smolts.

MATERIALS AND METHODS

Fan-Trap and Live-Box Design

Canadian fan-traps were used to capture smolts and to monitor their migration. The fan-traps were constructed of aluminum angle and were light, yet strong. The traps are 1.5 m square at the upstream opening and 3 m in length. From the mouth, they taper to a 0.3 m square opening (Figure 2).

The traps were attached to a cable, which was secured to large boulders in the river. The traps were further anchored by 20 mm steel reinforcing rods driven into the riverbed through eyelets on the bottom front edge of the traps. Aluminum tripods equipped with a pulley system were used to adjust the height of the downstream end of the traps. Elevation adjustments were made to accommodate different water levels and to prevent the downstream trap end from becoming submerged.

Live-boxes were connected to the downstream trap end by a camlock fitting. The live-boxes were rectangular with dimensions of 1.5 x 0.9 x 0.6 m. The front, back, and bottom were constructed of 1.9 cm (3/4 in) plywood and the remaining two sides of perforated aluminum plate. Styrofoam panels were attached to the two sides to provide flotation. The bottom was vented to provide continual water circulation (Figure 3).

Smolt Sampling and Enumeration

Four fan-traps were placed in the river on 11 May, and a fifth trap was added on 17 May. All five traps were fished until 14 July for a total time of 64 days. Weights (g), fork lengths (mm), and scale samples ("AWL" data) were collected daily from 20 randomly selected sockeye salmon smolts. In addition, the lengths of 30 randomly-selected sockeye salmon smolts were measured daily. An anesthetic, Tricaine methanesulfonate (MS-222), was administered to the smolts for ease in AWL data gathering.

Each year, prior to release, a portion of the Crooked Creek Hatchery sockeye salmon fry are marked for identification by clipping either the right or left ventral fin. The ventral fins of a minimum of 2,000 sockeye

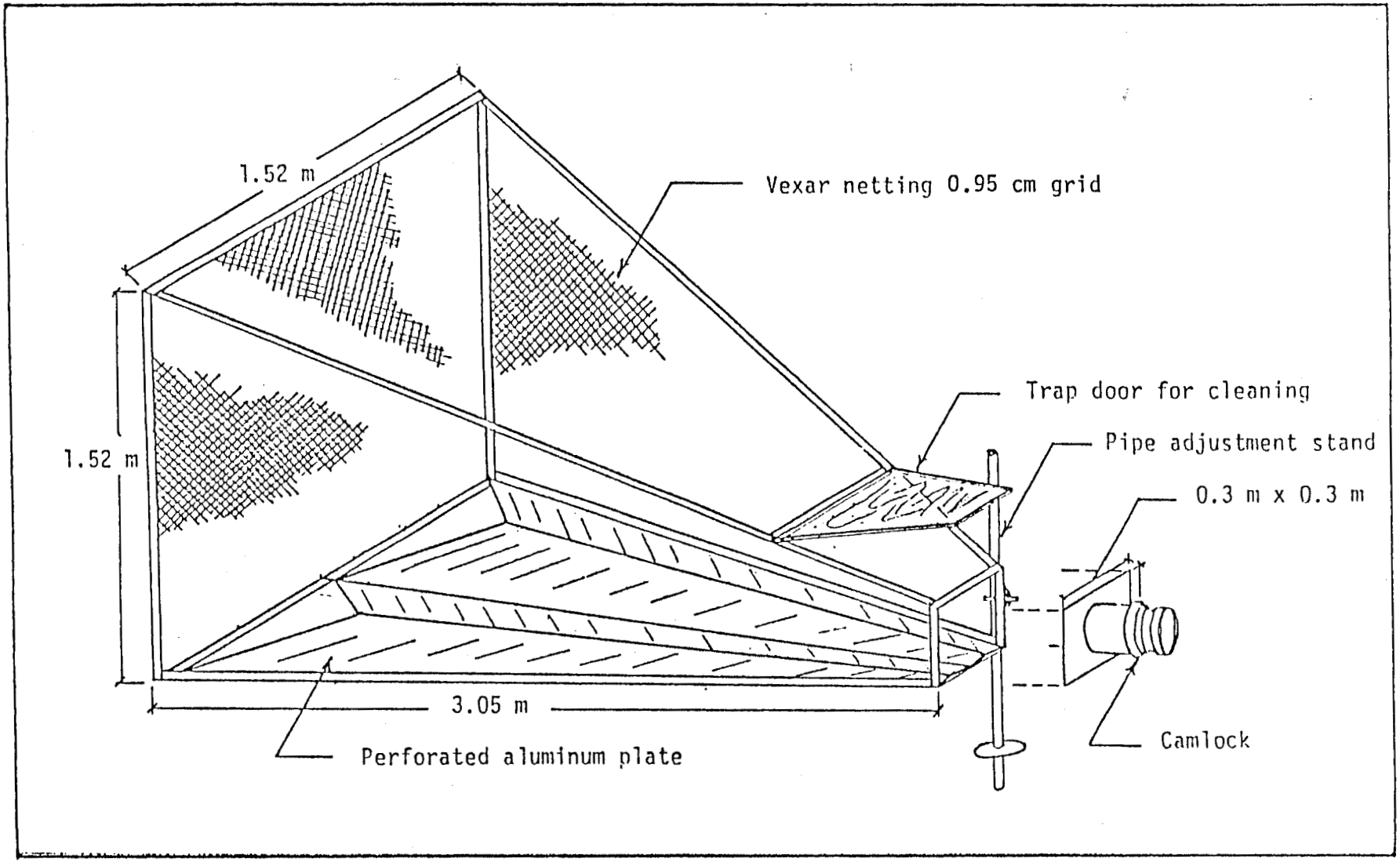

Figure 2. Schematic diagram of the Kasilof River smolt fan-trap.

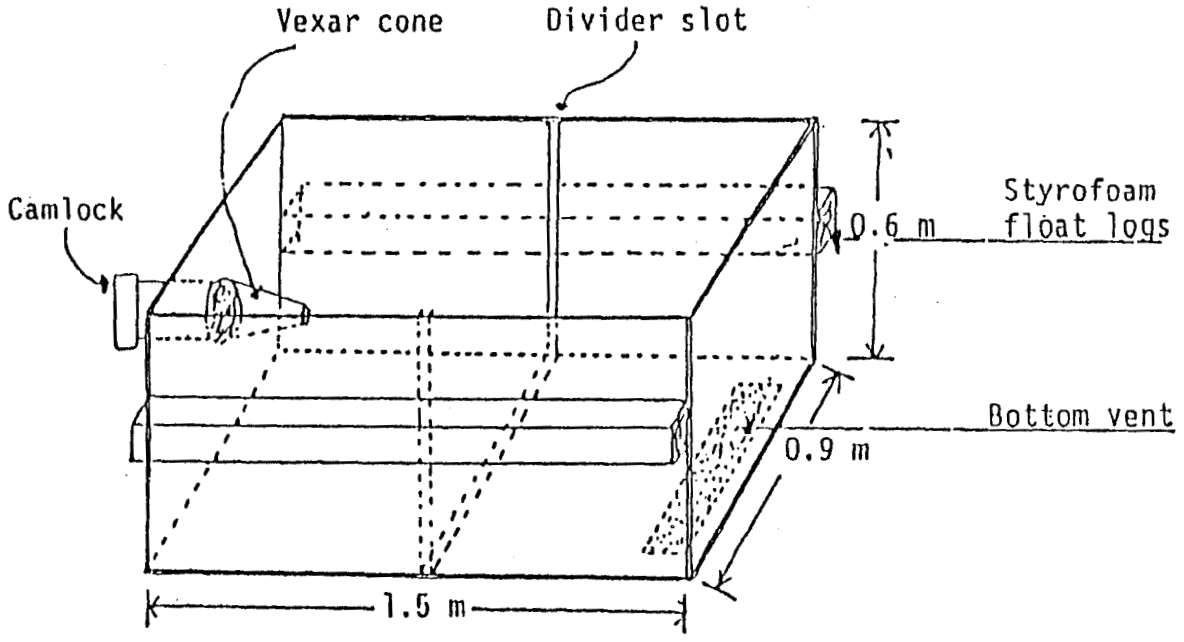

Figure 3. Schematic diagram of the live-box used to capture migrating smolts, Kasilof River.

salmon smolts were examined daily. The numbers of marked fish provided information to determine the hatchery-fry survival rate and contribution to the total migration.

On 16 June, the traps were checked every 3 h for 24 h to determine diel changes in the rate of smolt migration.

Smolt Population Estimate

The trap efficiency (interception rate) was estimated weekly, during the migration period, by a simple mark and recapture procedure. This involved placing several hundred smolts into a holding tank containing a Bismark Brown Y dye solution (1 g dye per 30 liter H_2O) for 30 minutes. The smolts became gold tinted and were easily distinguished from undyed smolts. The holding tank was equipped with an aeration system which provided a continuous flow of bottled oxygen. The tank was transported approximately 0.7 km upstream by riverboat, and the smolts were distributed evenly across the river. The number of dyed smolts recovered in the traps was used to estimate the proportion of smolts which were intercepted by the fan traps and to provide a measure of "trap efficiency". Rawson (1982) discusses the estimation of migrating smolt populations using the above technique. The population estimate is calculated according to the formula:

$$\hat{N} = \frac{nD}{d}\left[1 + \frac{D-d}{Dd}\right]$$

Where: $\hat{N}$ = estimated total population
D = number of fish dyed
d = number of dyed fish recaptured
n = number of unmarked smolt caught in traps

The estimated variance of $\hat{N}$ may be calculated from the formula (Rawson 1982):

$$\text{Var}(\hat{N}) = n(n + d)D(D - d)/d^3.$$

Using this quantity, a 95% confidence interval for $\hat{N}$ may be determined if we assume a normal distribution for N.

The percent of the smolt migration composed of age 1.0 and age 2.0 smolts was estimated for each weekly period using scales obtained from a fraction of each day's catch. This percentage was then applied to the estimated total outmigration for the same period to obtain estimates of the number of migrating smolts in each age class. The formulas used to obtain these estimates and their variances are discussed in Appendix C.

Hatchery Contribution and Survival Rate

In June 1980, 5.20 million sockeye fry from the Kasilof Hatchery were released into Bear Creek and Glacier Flats Creek, tributaries of Tustumena Lake. Of these, 65,400 were marked by ventral fin clips (Bear Creek-LV; Glacier Flats Creek-RV). Age 1.0 sockeye salmon smolts from the 1980 fry release migrated from Tustumena Lake during 1981, and age 2.0 smolts from the same release migrated during 1982.

In June 1981, 8.78 million hatchery-reared sockeye salmon fry were released from the Kasilof Hatchery into Bear Creek and Glacier Flats Creek. An estimated 452,000 of those fry were fin-clipped. The survivors of these fry emigrated as age 1.0 smolts in 1982.

During 1982 the sockeye salmon smolts that were caught in the fan traps were inspected for missing ventral fins. The number of marked fish recovered was then used to estimate the hatchery-fry survival and contribution to the total smolt migration. The formula used for calculating the variance of this estimate was derived by Reed (1981), and it is available in an HP-97 program from the FRED Biometrics Section in Anchorage (Howe 1981).

Physical Parameters

Water velocity in meters per second was measured with a Teledyne Gurley meter. Velocity measurements were taken 2 m in front of each trap to avoid any turbulence created by the traps. Discharge was estimated on five separate days (27 May, 3 June, 10 June, 17 June, and 5 July) to correlate with trends in the smolt migration. Total discharge was also measured periodically throughout the study using a U.S. Geological Survey water gauge located at the Kasilof River-Sterling Highway bridge.

Water temperatures (°C) were recorded daily at the smolt sampling site to assess any relationship between smolt migration and water temperature.

RESULTS

Smolt Enumeration and Sampling

Between 12 May and 14 July 418,592 sockeye salmon smolts were captured in the five fan traps (Table 1). The peak catch occurred during the first 3 weeks of June when 291,969 smolts (69.7% of the total catch) were caught. The highest daily catch occurred on 5 June when 43,725 smolts were captured (Figure 4).

Scales were collected and weights and lengths of 714 sockeye salmon smolts were measured. The mean lengths of age 1.0 and age 2.0 smolts were 69 mm and 82 mm, respectively (Table 2). The mean weights of age 1.0 and age 2.0 smolts were 2.9 g and 4.8 g, respectively (Table 2).

Table 1. Daily catches of sockeye salmon smolts by trap, Kasilof River, 1982.

Date	Trap Number 1	2	3	4	5	Daily Total
May						
12	0	0	2	7	0	9
13	0	0	5	8	0	13
14	0	0	8	5	0	13
15	1	0	16	4	0	21
16	0	1	7	2	0	10
17	0	0	5	5	0	10
18	0	0	12	3	0	15
19	0	0	12	8	0	20
20	0	0	2	1	0	3
21	0	0	0	1	1	2
22	0	1	99	24	0	124
23	0	0	330	60	4	394
24	1	1	1,409	104	0	1,515
25	2	8	2,976	264	3	3,253
26	0	0	1,552	452	1	2,005
27	0	1	1,395	251	0	1,647
28	0	1	503	139	0	643
29	1	9	1,093	249	2	1,354
30	4	9	3,585	715	1	4,314
31	5	9	7,150	2,065	13	9,242
June						
01	10	10	8,802	2,639	18	11,479
02	21	49	13,065	5,271	45	18,451
03	18	21	4,438	1,504	29	6,010
04	62	45	14,504	6,460	41	21,112
05	84	210	34,387	8,983	61	43,725
06	15	92	8,727	1,212	14	10,060
07	40	52	2,674	700	15	3,481
08	48	35	7,172	1,781	112	9,148
09	102	246	5,519	1,657	22	7,546
10	132	140	4,005	1,134	31	5,442
11	144	180	10,228	784	95	11,431
12	70	663	17,512	4,100	154	22,499
13	375	787	14,022	2,832	271	18,287
14	261	872	15,967	4,174	280	21,554
15	112	750	7,216	1,742	203	10,023
16	108	463	5,955	1,479	94	8,099
17	120	379	4,453	1,497	164	6,613
18	342	3,425	17,950	4,111	199	26,027
19	104	359	4,216	985	69	5,733

-Continued-

Table 1. Continued.

Date	Trap Number 1	2	3	4	5	Daily Total
June (continued)						
20	183	784	10,294	1,959	124	13,344
21	199	683	9,206	1,611	166	11,865
22	74	256	4,043	1,217	53	5,643
23	402	1,075	13,474	3,546	112	18,609
24	196	541	5,200	2,209	137	8,283
25	93	336	2.028	726	45	3,228
26	112	325	2,799	1,244	63	4,543
27	121	672	4,702	1,984	69	7,548
28	72	175	976	585	43	1,851
29	97	125	1,178	518	52	1,970
30	270	1,090	6,101	2,035	297	9,793
July						
01	116	610	3,515	a/	133	5,858
02	193	492	2,417	a/	50	4,214
03	108	299	a/	a/	70	477
04	371	642	a/	a/	90	1,103
05	224	519	a/	a/	82	825
06	264	446	a/	a/	68	778
07	141	441	1,152	604	59	2,397
08	295	579	938	59	31	1,902
09	107	177	715	357	49	1,405
10	103	133	212	30	12	490
11	40	112	111	151	13	427
12	34	118	172	101	5	430
13	42	100	258	165	24	589
14	29	121	169	96	55	470
Tot.	6,067	19,670	304,217	84,794	3,844	418,592
% of Total	1.4%	4.7%	72.7%	20.3%	0.9%	

a/ Traps not fishing because of high water.

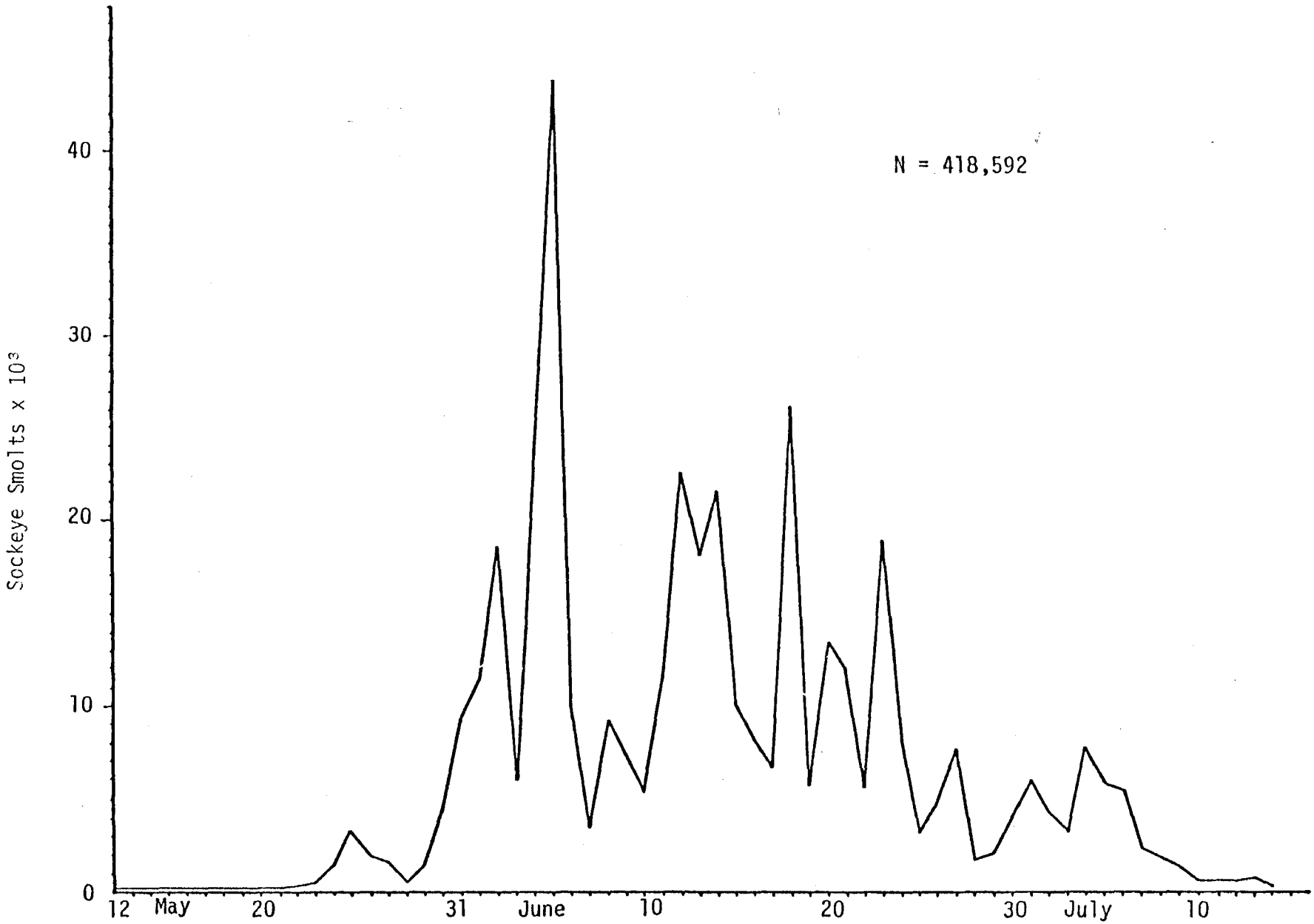

Figure 4. Daily catch of sockeye salmon smolts in the Kasilof River, 12 May - 14 July, 1982. Total catch for the period was 418,592.

Table 2. Mean lengths, weights and standard deviations (S.D.) of sockeye salmon smolts, Kasilof River, 1982.

Sample Period	Dates	Mean Length (mm)	S.D.	Mean Weight (g)	S.D.	Sample Size
		Age 1.0				
1	5/12-5/15	64	3.6	2.0	0.5	25
2	5/16-5/22	65	5.6	2.6	0.7	69
3	5/23-5/29	70	3.5	3.0	0.5	54
4	5/30-6/05	69	2.9	3.1	0.5	39
5	6/06-6/12	69	3.2	2.9	0.5	106
6	6/13-6/19	68	3.4	2.7	0.5	81
7	6/20-6/26	71	3.9	3.2	0.7	67
8	6/27-7/03	71	3.6	3.1	0.5	85
9	7/04-7/11	71	3.9	3.0	0.7	40
	Season	69[a/]		2.9[a/]		566
		Age 2.0				
1	5/12-5/15	80	4.2	3.6	0.4	3
2	5/16-5/22	83	3.8	5.0	0.6	10
3	5/23-5/29	84	3.9	5.2	0.7	38
4	5/30-6/05	80	2.8	4.8	0.7	14
5	6/06-6/12	82	4.5	4.6	0.9	38
6	6/13-6/19	82	4.4	4.5	0.8	17
7	6/20-6/26	83	5.3	5.0	0.9	13
8	6/27-7/03	81	4.9	4.8	0.9	15
9	7/04-7/11	-	-	-	-	0
	Season	82[a/]		4.8[a/]		148

a/ Weighted by total population estimate of respective age smolts.

During 1982, 80% of the smolts were age 1.0 and 20% age 2.0. The peak migration of age 1.0 and age 2.0 smolts occurred during the same week (30 May - 5 June). Age 2.0 smolts comprised 41% of the smolts sampled during the peak week (23-29 May), but the proportion of age 1.0 smolts increased rapidly during the remainder of the migration (Table 3).

In addition to sockeye salmon, nine other fish species, including three other Pacific salmon species, were captured in the Kasilof River traps (Table 4).

Of these, chinook salmon (Onchorhynchus tshawytscha) were most abundant; 2,974 were caught, of which 677 were smolts.

Smolt Population Estimate

Nine trap efficiency tests were conducted during the smolt migration. The proportion of the marked smolts that were recovered in the traps was not consistent among the nine tests (Figure 5), as verified by a chi-square test (χ^2 = 53.2, d.f. = 7). For estimating the magnitude of the smolt migration, the nine trap efficiency tests were divided into four groups. A chi-square test for each group indicated no differences in the mark recovery rate (Table 5).

Trap efficiency was highest during the first period (12 May-29 May) with an 11.6% recovery rate. This high recovery rate was due to low water discharge that resulted in a greater percentage of the total volume passing through the smolt traps. An estimated 96,200 sockeye salmon smolts migrated during the first period (Table 6).

During the second period (30 May-2 July), a mean trap efficiency of 8.12% was obtained from four different mark and recapture tests (χ^2 = 5.66, d.f. = 3). During this period an estimated 4,670,000 smolts migrated (Table 6) or 91% of the total smolt migration.

For the 4-day duration of the third period (3 July-6 July), two of the five smolt traps were not fishing because of high water.

The single mark and recovery test performed during this period showed a 2.7% recovery rate. An estimated 133,000 smolts migrated during the third period (Table 6).

The recovery rate for the fourth period (7 July-14 July), when all traps were operating again, declined to 3.41%. The decline was due to increased water discharge resulting in decreased trap volume and efficiency. An estimated 242,000 smolts migrated during this period (Table 6).

As was the case in 1981, the bulk of the 1982 smolt migration occurred in several pulses of large numbers of smolts going out at once (Figure 6).

The age composition of the smolt run was estimated by weekly periods according to the method discussed in Appendix C. The results (Table 7) indicate that the run timing of the two age classes was similar, although

Table 3. Summary of age composition estimates, Kasilof River, 1983.

Period	Sample Size	Sample Composition Age 1.0	Sample Composition Age 2.0	Estimated Percent Age 1.0	95% Confidence Interval for Percent Age 1.0[a/]
12-15 May	28	25	3	89.3	[70.6, 97.2]
16-22 May	79	69	10	87.3	[77.5, 93.4]
23-29 May	92	54	38	58.7	[47.9, 68.7]
30 May-5 June	53	39	14	73.6	[59.4, 84.3]
6-12 June	144	107	37	74.3	[66.2, 81.1]
13-19 June	98	81	17	82.7	[73.4, 89.3]
20-26 June	80	67	13	83.8	[73.5, 90.7]
27 Jun-27 Jul	100	85	15	85.0	[76.1, 91.1]
4-10 July	40	40	0	100.0	

a/ 95% confidence intervals calculated from equations (1.26) and (1.27) of Fleiss (1981).

Table 4. List of species captured by fan-traps in the Kasilof River, 1980, 1981, and 1982.[a/]

Common Name	Scientific Name	Year 1980	1981	1982
Sockeye salmon	Oncorhynchus nerka (Walbaum)	64,535	155,531	418,592
Chinook salmon	Oncorhynchus tshawytscha (Walbaum)	335 2,933	1,413 8,367	677 2,297
Coho salmon	Oncorhynchus kisutch (Walbaum)	45	107	828
Pink salmon	Oncorhynchus gorbuscha (Walbaum)	436	19,508	80
Dolly Varden	Salvelinus malma (Walbaum)	90	132	115
Rainbow trout	Salmo gairdneri (Richardson)	1	0	0
Round whitefish	Prosopium cylindraceum (Phallas)	3	0	1
Eulachon	Thaleichthys pacificus (Richardson)	0	9	3
Slimy sculpin	Cottus cognatus (Richardson)	681	4,929	2,580
Threespine stickleback	Gasterosteus aculeatus (Linnaeus)	181	2,994	1,684

a/ Note: These numbers are not necessarily comparable from year to year since the trap efficiencies varied, both within and between years.

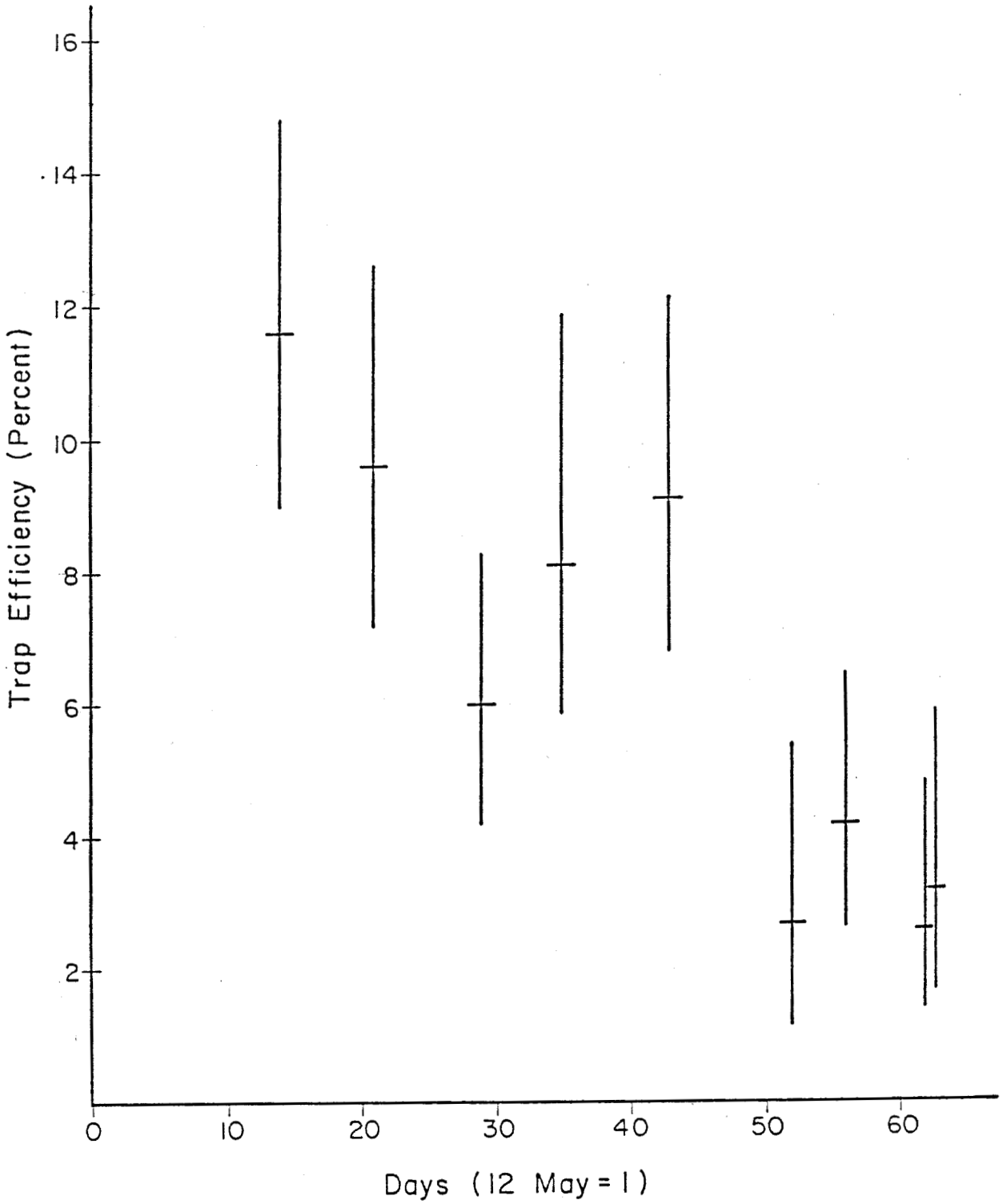

Figure 5. Results of the nine Kasilof River dye tests, 1982. The horizontal lines indicate the estimated trap efficiencies. The vertical lines represent 95% confidence intervals for the estimated trap efficiencies.

Table 5. Summary of dye-mark recovery results, Kasilof River, 1982.

Date	Dyed Fish Released	Dyed Fish Recovered	Percent Dyed Fish Recovered	95% Confidence Interval [a]
Period 1:				
26 May	500	58	11.6	[9.0, 14.8]
Period 2:				
2 June	500	48	9.6	[7.2, 12.6]
10 June	569	34	6.0	[4.2, 8.3]
16 June	508	41	8.1	[5.9, 10.9]
24 June	504	46	9.1	[6.8, 12.1]
Subtotal	2,081	169	8.1	[7.0, 9.4]
Period 3:				
3 July	299	8	2.7	[1.2, 5.4]
Period 4:				
7 July	500	21	4.2	[2.7, 6.5]
12 July	421	11	2.6	[1.4, 4.8]
13 July	340	11	3.2	[1.7, 5.9]
Subtotal	1,261	43	3.4	[2.5, 4.6]

a/ based on equations (1.26) and (1.27) of Fleiss (1981).

Table 6. Summary of smolt outmigration estimates, Kasilof River, 1982. Ninety-five percent confidence intervals are indicated in brackets below the estimates.

Period	Dyed Fish Released (D)	Dyed Fish Recovered (d)	Unmarked Fish Caught (n)	Outmigration Estimate ($\hat{N}$) (thousands)
12-29 May	500	58	11,051	96.2 [73.2-119]
30 May-2 July	2,081	169	377,015	4,670 [4,000-5,340]
3-6 July	299	8	3,183	133 [51.8-214]
7-14 July	1,261	43	8,110	242 [172-312]
Overall				5140 [4,460-5,820]

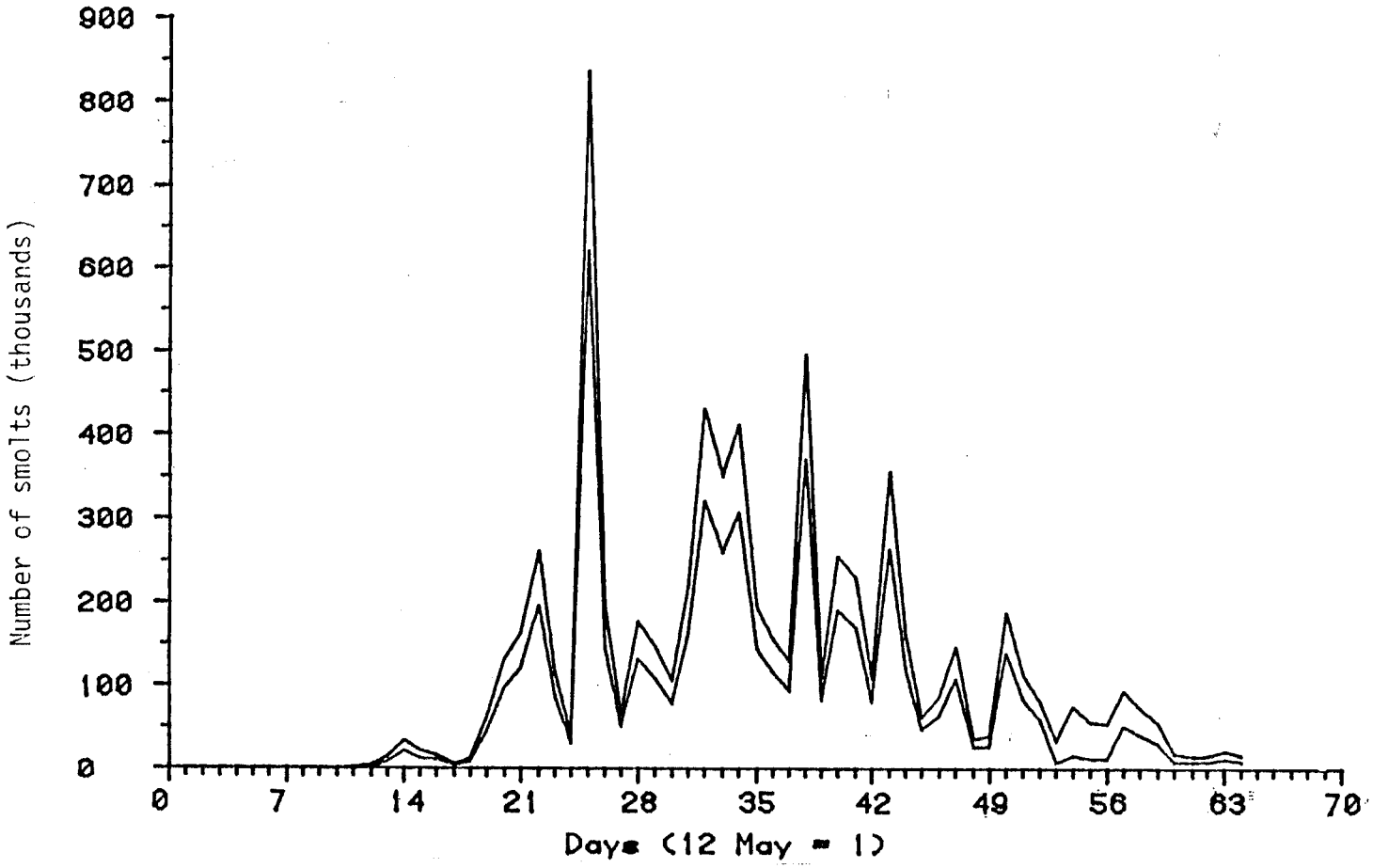

Figure 6. The two lines represent the upper and lower bounds of the 95% confidence interval for each day's estimated total sockeye salmon smolt migration in the Kasilof River, 1982.

Table 7. Summary of the weekly estimates of smolt migration by age class, Kasilof River, 1982. All quantities are in thousands of fish.

Sample Period	Age 1 Migration Estimate	Age 1 95% Conf. Interval [a]	Age 2 Migration Estimate	Age 2 95% Conf. Interval [a]
12-15 May	0.380	[0.28, 0.60]	0.05	[0, 0.11]
16-22 May	4.50	[3.2, 5.9]	0.7	[0.2, 1.1]
23-29 May	82.6	[75.5, 89.7]	12.0	[5.1, 19.0]
30 May-5 June	1040	[864, 1270]	374	[197, 551]
6-12 June	640	[529, 751]	222	[152, 291]
13-19 June	986	[819, 1150]	205	[112, 301]
20-26 June	680	[56.2, 798]	132	[63.8, 201]
27 June-2 July	329	[274, 383]	58.0	[29.6, 86.4]
3-6 July	133	[51.8, 214]	0	
7-14 July	242	[172, 312]	0	
Overall	4140	[3180, 4470] [b]	1010	[780, 1230] [b]

a/ The confidence intervals were calculated as described in Appendix C.

b/ The overall variance was calculated by summing the individual weekly variances. The confidence interval was calculated by assuming a normal distribution for the overall estimate.

the second peak in the age 1.0 migration was not reflected in the migration of age 2.0 smolts (Figure 7). Overall, the run was estimated to be composed of 4.1 million age 1.0 smolts and 1.0 million age 2.0 smolts.

The total estimated biomass of sockeye salmon smolts migrating from Tustumena Lake was 16,900 kg. This estimate was calculated by multiplying the weekly mean weights of age 1.0 and 2.0 smolts by the weekly estimated outmigration and then summing the results (Table 8).

Physical Parameters

Kasilof River Discharge:

During 1982, the discharge in the Kasilof River ranged from 16.2 m^3/s on 4 May to 79.7 m^3/s on 14 July. Thus the overall discharge was below the long term average (19.0 m^3/s - May, 41.3 m^3/s - June, 126.4 m^3/s - July) reported by Scully (1978). Discharge readings taken during 1982 at the U.S.G.S. Gauge on the Kasilof River-Sterling Highway Bridge and those taken downstream at the smolt site appear in Appendix B.

The percentage of the total discharge passing through the traps was nearly constant throughout the smolt migration. There was a direct correlation between the number of smolts caught and the discharge within the river (Figure 8). The highest smolt catches were consistently made in the center of the river where the greatest discharge occurred.

Water Temperature:

The lowest water temperature recorded during the smolt migration was 4.4° C (40° F). The highest temperature was 12.2° C (54° F) During the early part of the migration there was no direct relationship between rising water temperatures and numbers of sockeye salmon smolts.

Hatchery Contribution and Survival Rate

A total of 55,835 sockeye salmon smolts or 13.3% of the smolts captured were examined for clipped ventral fins. There were 506 fin clipped smolts recovered [235 RV (right ventral) from Bear Creek stock and 271 LV (left ventral) from Glacier Flats Creek stock]. Of the 506 recovered, 15 or 3.0% were age 2.0 smolts.

Reed's (1981) formulas were used to calculate the survival rate and hatchery contribution to the 1982 sockeye smolt migration as well as the variances of these quantities. Survival to age 1.0 of marked hatchery sockeye fry released into Tustumena Lake in 1981 was estimated at 9.98%. The complete survival rate for the 1981 release year will not be known until the age 2.0 smolts migrate in 1983. The total survival rate of 1980-released fry was estimated to be 5.83% (5.52% to age 1.0, .31% to age 2.0).

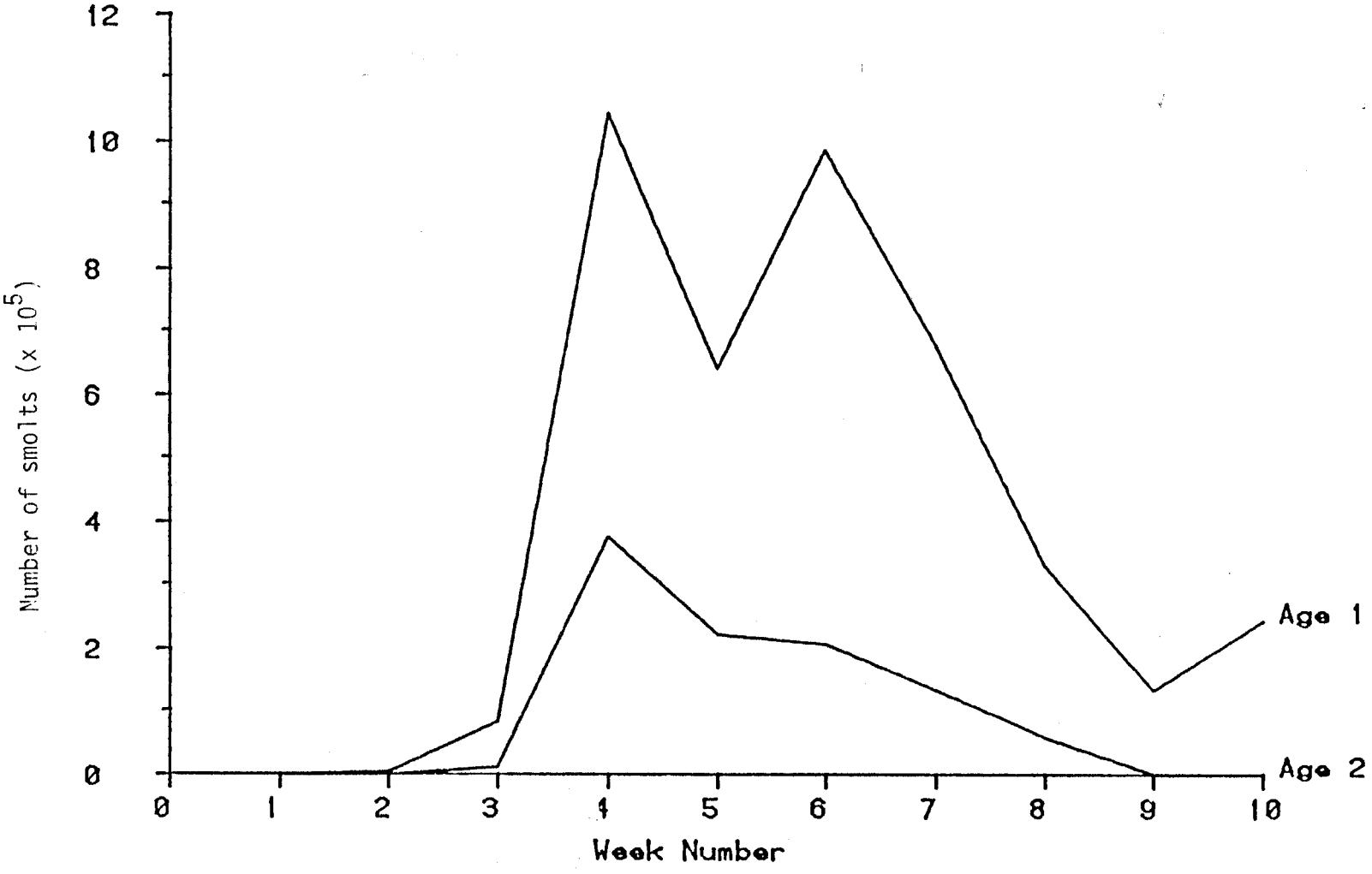

Figure 7. Estimated migration patterns of age 1.0 and age 2.0 sockeye salmon smolts, by week, Kasilof River, 1982.

Table 8. Estimated sockeye salmon smolt biomass migrating from Tustumena Lake, 1982. Age 1 and 2 smolt are indicated by 1.0 and 2.0, respectively.

Sample Period	Mean Weight (g)		Estimated No. Migrants		Estimated Biomass (kg)	
	1.0	2.0	1.0	2.0	1.0	2.0
5/12-5/15	2.0	3.6	380	50	0.8	.18
5/16-5/22	2.6	5.0	4,500	700	11.7	3.5
5/23/5/29	3.0	5.2	82,600	12,000	248	62.4
5/30-6/05	3.1	4.8	1,040,000	374,000	3,130	1,790
6/06-6/12	2.9	4.6	640,000	222,000	1,860	1,020
6/13-6/19	2.7	4.5	986,000	206,000	2,660	928
6/20-6/26	3.2	5.0	680,000	132,200	2,180	661.0
6/27-7/02	3.1	4.8	329,000	58,000	1,020	278
7/03/7/06	3.0[a/]	...	133,000	0	399.0	0
7/07-7/14	2.9[a/]	...	242,000	0	698.9	0
Season	2.9	4.8	4,140,000	1,010,000	13,200	4,750

Total Estimated Biomass = 16.9 x 10^3 kg
16.9 x 10^3 kg/29,107 ha = .58 kg/ha

a/ Mean season weight used as no weight data were collected during this period. recorded on 11 July. The mean water temperatures for May, June, and July were 5.5° C (42° F), 11.1° C (52° F), and 11.1° C (52° F), respectively.

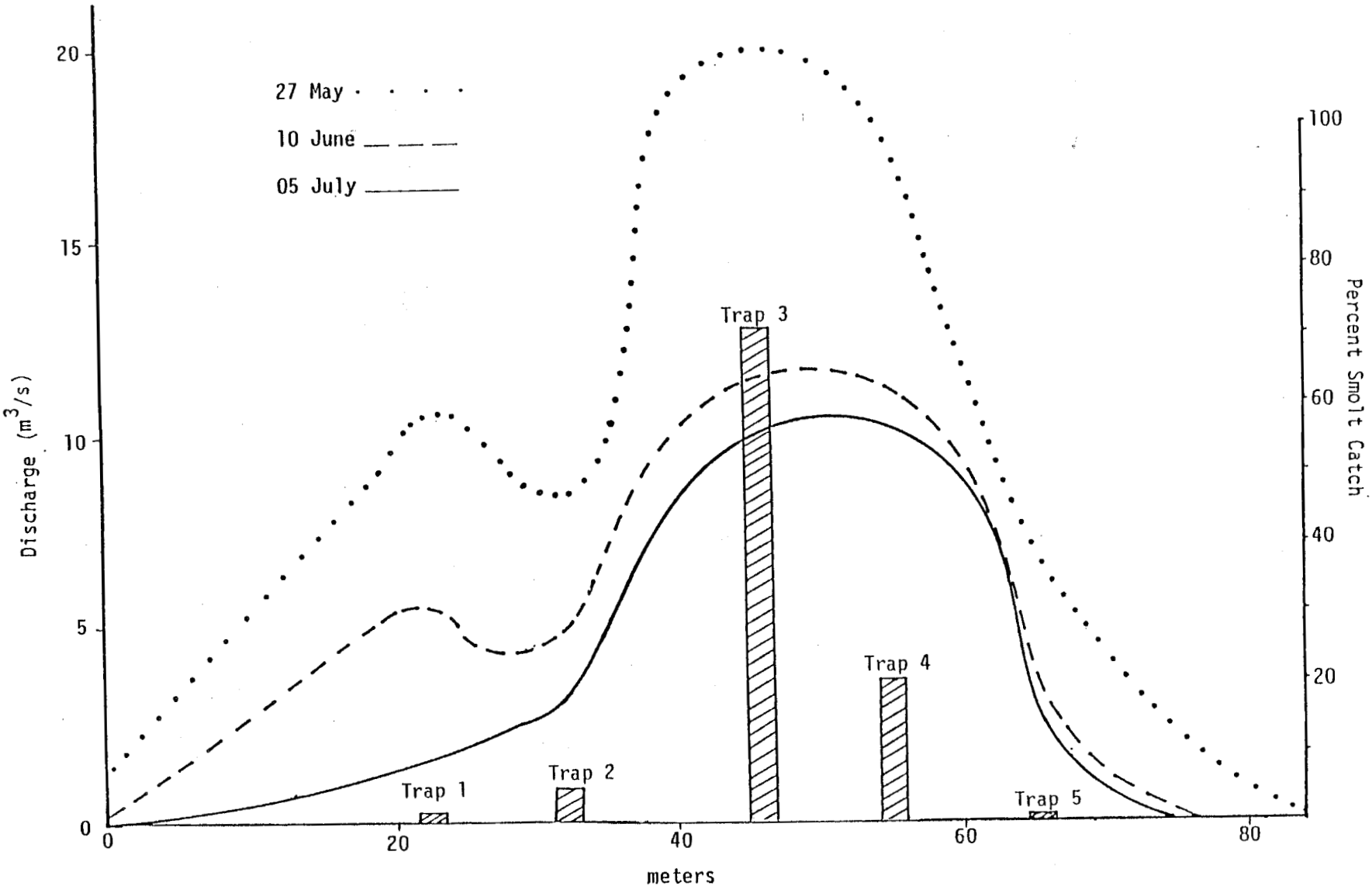

Figure 8. The vertical bars represent the percent of the 1982 Kasilof River sockeye salmon smolt catch by trap. Distance (m) from the river bank is noted. The solid and broken lines represent the discharge on three different dates at the trap site (see key above).

The number of hatchery produced smolts in the 1982 Kasilof River sockeye salmon migration for each one class was estimated by multiplying the above survival rate estimates by the total number of fry released in the respective year (Table 9). Table 10 is a summary, by brood year, of the estimated Kasilof Hatchery contribution to the Kasilof River smolt migration for the year 1980.

With an increase in water temperature there was an increase in the number of migrating smolts, however, after 18 June the numbers of smolts caught declined while the water temperature leveled off (Figure 9).

Diel Distribution:

Between 1200 h on 16 June and 1200 h on 17 June, the traps were emptied and the smolts were counted at 3-hour intervals. The peak of the migration occurred between 0300 and 0800h (Figure 10). The fewest smolts were captured between 1500 and 2100h. This was essentially the same diel pattern we observed during 1981 (Figure 10).

DISCUSSION

Smolt Enumeration

Three years of smolt enumeration have been completed on the Kasilof River (1980-1982). In addition to estimating the total smolts migrating, we have estimated hatchery contribution and collected AWL (age-weight-length) information.

For the second successive year, our estimates indicate that both the total sockeye salmon smolt migration and the hatchery contribution to the migration have increased over those values obtained for the 1980 smolt migration. We have observed no significant change in condition of sockeye salmon smolts as measured by average weight (Figure 11) and length (Figure 12)

There has been a gradual increase in the percentage of age 2.0 smolts migrating from Tustumena Lake (Figure 13), however, the composition of age 2.0 smolts recorded in 1982 (18%) is still within the normal range observed elsewhere in Central Cook Inlet (Flagg, 1982).

We have compared the condition of hatchery smolts, as identified by fin-clips, with wild smolts. Mean lengths and weights of age 1.0 and age 2.0 fin-clipped sockeye salmon smolts from the Kasilof River in 1982 (Table 11) compare favorably to unmarked smolts (Table 2).

The technique used to capture and estimate the number of sockeye smolt migrants has improved since our initial effort in 1980. We modified the basic trap design in 1981 to improve performance under high water conditions and we have also increased the number of mark and recapture experiments used to calibrate trap efficiency. Only one dye mark/recovery

Table 9. Summary of the estimated contribution of hatchery produced sockeye salmon to the Kasilof River 1982 smolt migration.

Brood Year	Release Year	Smolt Age	Estimated % Survival	Total Release	Estimated Hatchery Contribution
1979	1980	2.0	.31[a/]	5.20×10^6	16,100
1980	1981	1.0	9.98[b/]	8.78×10^6	876,000

a/ Does not include survival to age 1.0 smolts in 1981.
b/ Does not include survival to age 2.0 smolts in 1983.

Table 10. Summary of the estimated contribution of hatchery-produced sockeye salmon to the Kasilof smolt migration, 1980-1982.

Brood Year	Release Year	Total Release	Estimated Survival %			Est. Hatchery Contrib.	
			Age 1.0	Age 2.0	Total	No.	%
1978	1979	7.76×10^a	0.31	0.15	.46	37,500	0.46
1979	1980	5.20×10^a	5.52	0.31	5.83[a/]	303,000[a/]	13.1[a/]
1980	1981	8.78×10^a	9.98		9.98[a/]	876,000[a/]	17.4[a/]

a/ Age 2.0 smolts

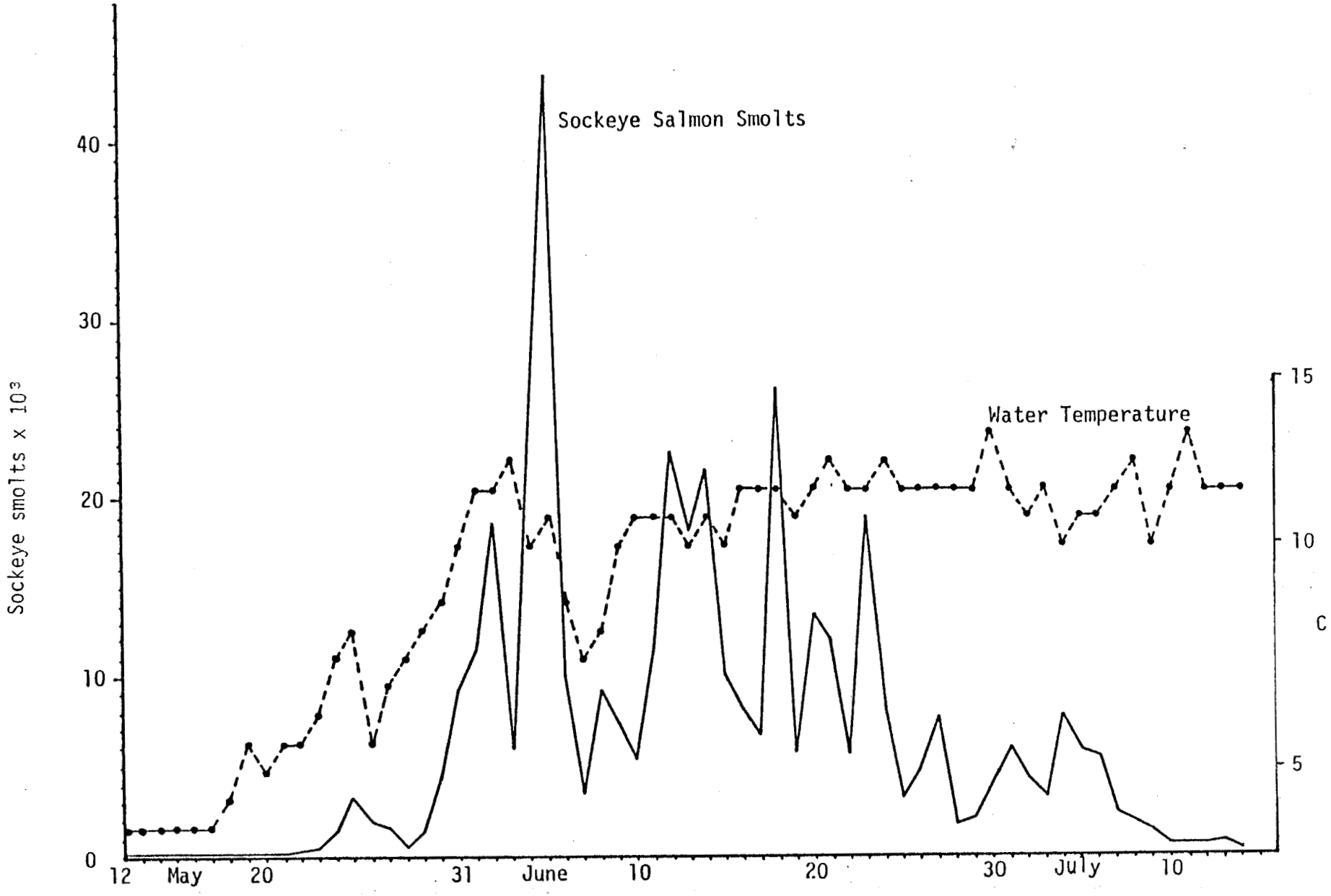

Figure 9. Daily catches of sockeye salmon smolts and average daily water temperature (C), Kasilof River, 1982.

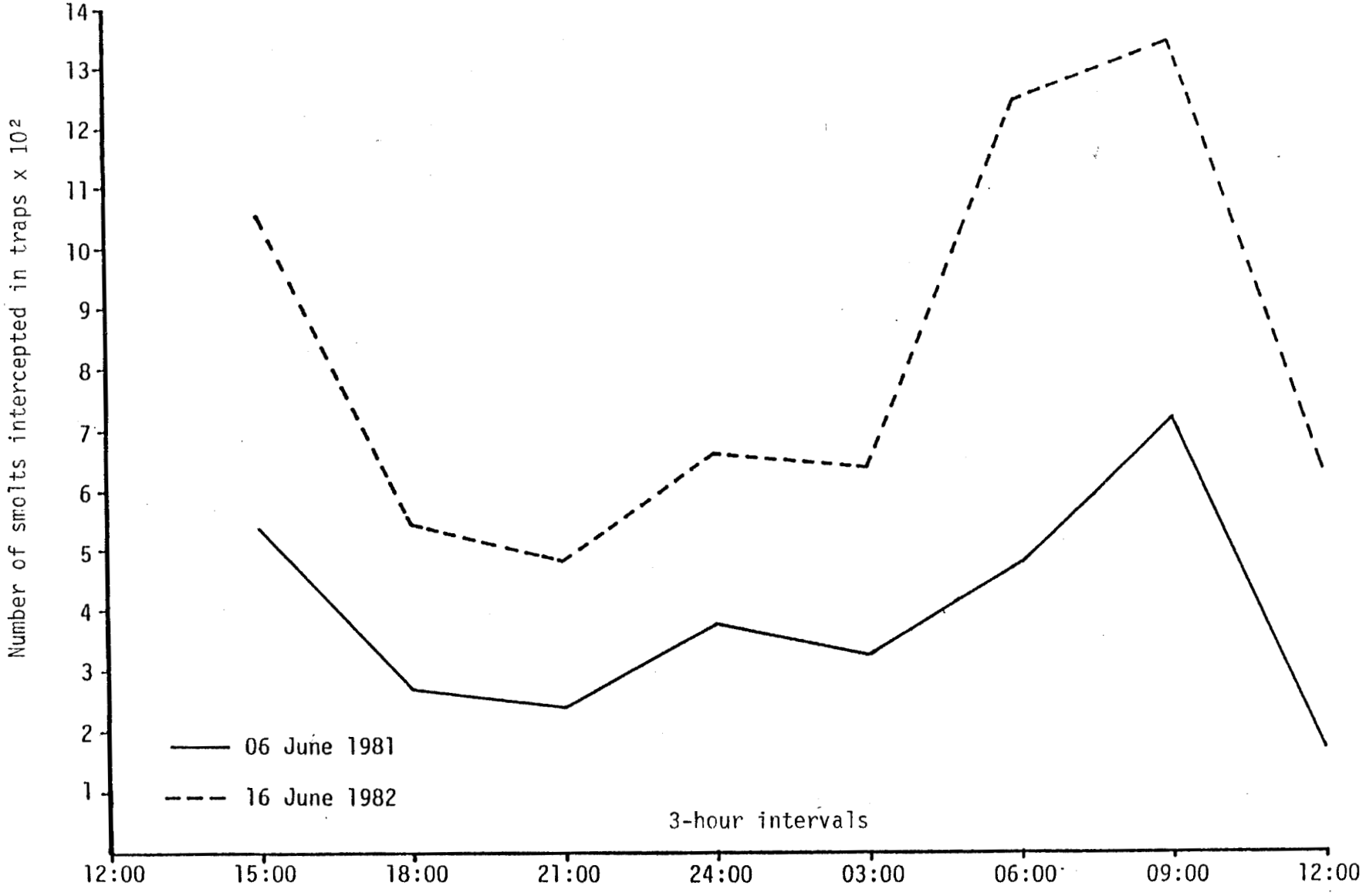

Figure 10. Hourly outmigration pattern of sockeye salmon smolts in the Kasilof River. Smolts enumerated at 3-hour intervals over a 24-hour period.

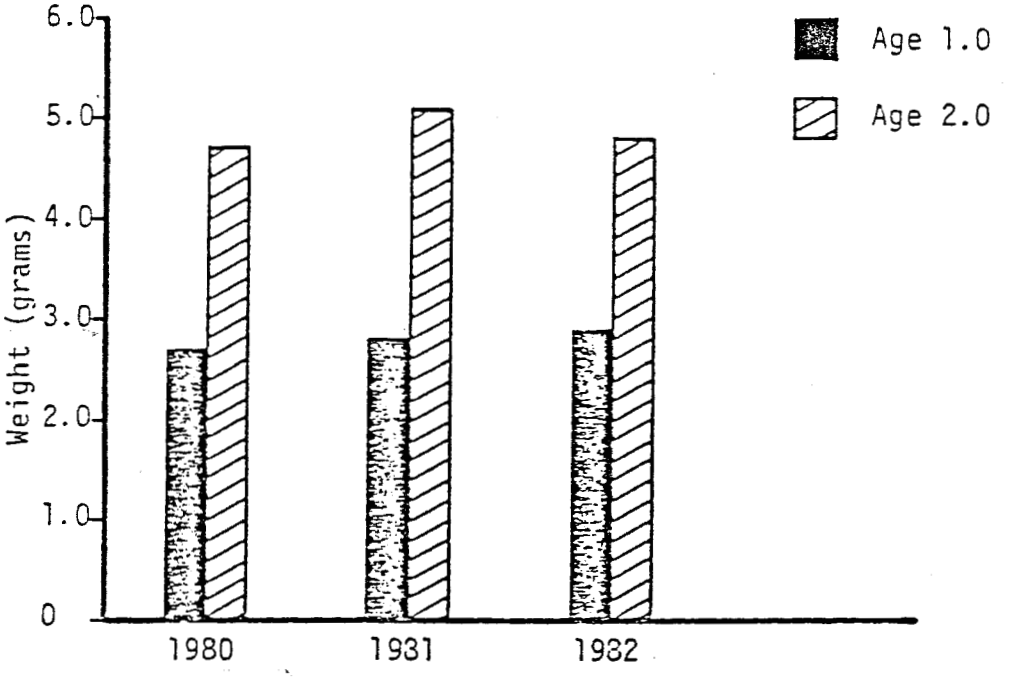

Figure 11. Mean weight (grans of age 1.0 and 2.0 sockeye salmon smolts in Kasilof River, Alaska, sampling years 1980-1982.

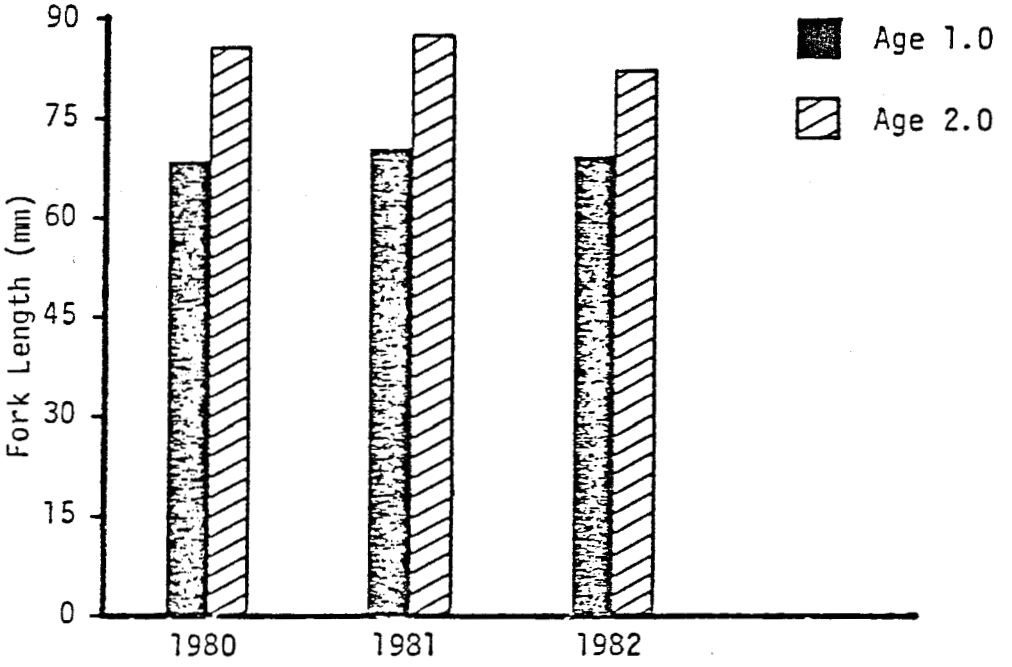

Figure 12. Mean fork length of age 1.0 and age 2.0 sockeye salmon smolts in Kasilof River, Alaska, sampling years 1980-1982.

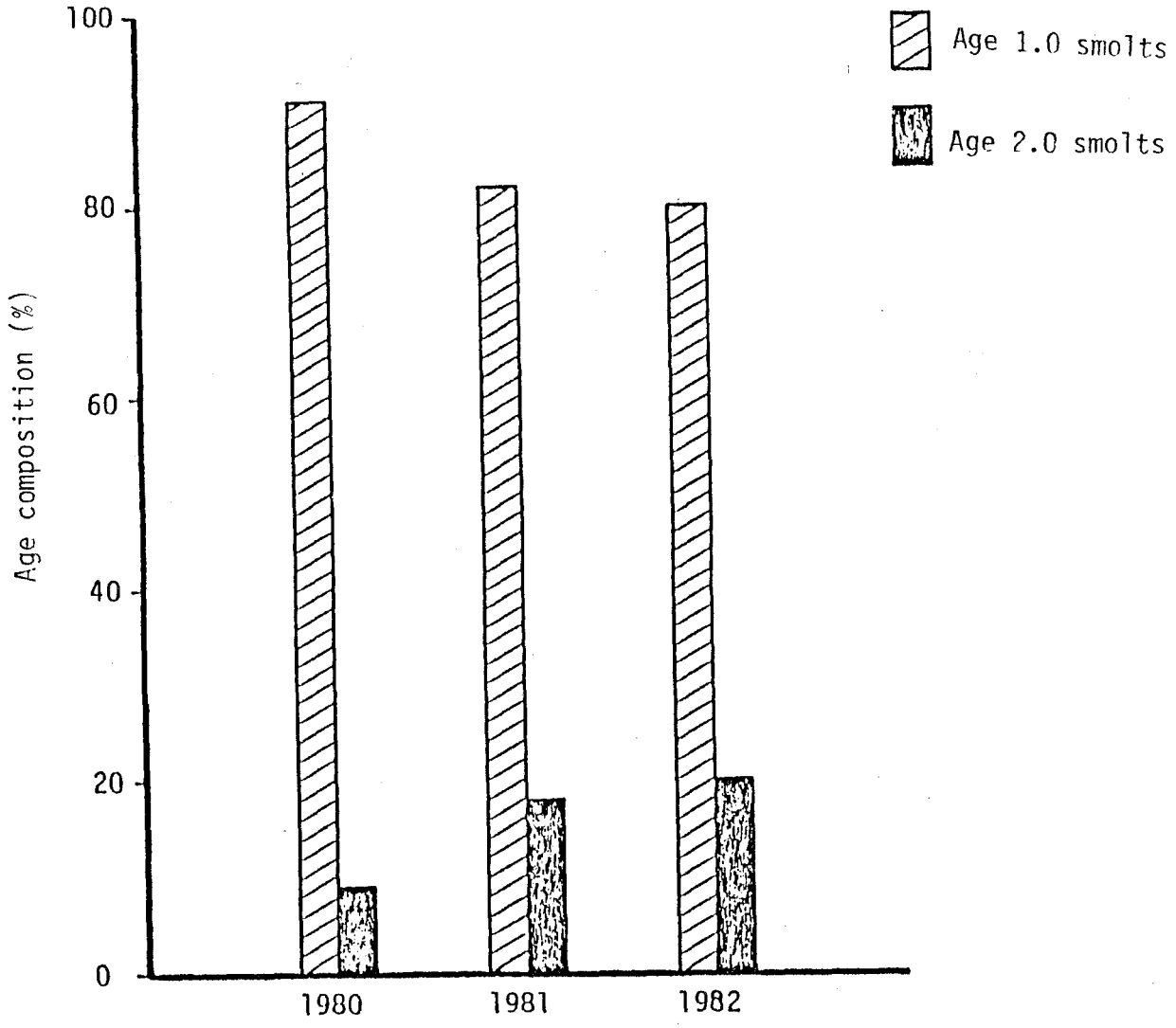

Figure 13. Percent age composition of sockeye salmon smolts in the Kasilof River, Alaska, 1980, 1981, and 1982.

Table 11. Mean lengths and weights of fin-clipped sockeye salmon smolts, Kasilof River, 1982. Dots (...) indicate no samples were taken.

Sample period	Dates	Mean length (mm)	S.D.	Mean weight (g)	S.D.	Sample number
		Age 1.0				
1	5/12-5/15	...	...	...	...	0
2	5/16-5/22	...	...	...	...	0
3	5/23-5/29	69	3.4	3.0	0.4	41
4	5/30-6/05	68	3.4	2.8	0.4	89
5	6/06-6/12	68	3.7	2.7	0.5	124
6	6/13-6/19	68	3.3	2.6	0.5	76
7	6/20-6/26	69	4.0	3.0	0.5	76
8	6/27-7/03	69	3.5	3.0	0.5	66
9	7/04-7/11	68	4.3	2.8	0.7	19
	Season	68[a/]	---	2.8[a/]	---	491
		Age 2.0				
1	5/12-5/15	...	...	...	...	0
2	5/16-5/22	...	...	...	...	0
3	5/23-5/29	79	5.0	4.5	0.8	3
4	5/30-6/05	75	1.5	3.8	0.4	3
5	6/06-6/12	74	2.3	3.8	0.4	3
6	6/13-6/19	75	0.0	3.4	0.1	3
7	6/20-6/26	77	0.0	4.0	0.0	1
8	6/27-7/03	81	0.0	4.8	0.0	1
9	7/04-7/11	80	0.0	4.3	0.0	1
	Season	77[a/]	---	3.9[a/]	---	15

a/ Weighted by total population estimate for each respective age.

test was conducted during 1980 when high water and debris problems were encountered throughout the smolt migration. We now believe that our estimate for 1980 was conservative.

Smolt monitoring will continue in 1983 using basically the same procedures as used in 1982. Dye mark/recovery estimations will be made on a weekly basis to calibrate trap efficiency as water flows change. We plan to move our release site for dye marked smolts back to the Sterling Highway Bridge, since the closer release location used during 1982 may not have allowed a random distribution of smolts across the river at the trap site. For dye marking we also plan to capture smolts used in a fan trap at the bridge instead of capturing them at the lower river traps. There will be less handling of smolts, and logistical problems experienced in the past should be greatly reduced.

Also under consideration for 1983 is a plan to conduct at least one dye-mark and recapture test during the early morning hours when most smolts are migrating. This may indicate if the distribution of marked fish recaptured at our traps is related to diel timing of migration, rather than release distance from the trap site.

The $5.1 \pm 0.7 \times 10^6$ 1982 sockeye salmon smolt migration estimate for Tustumena Lake is the highest observed since smolt enumeration began in 1980. If Thorne's (1982) hydroacoustic estimate of $5.9 \pm 3.6 \times 10^6$ fall fry in Tustumena Lake in September 1981 is assumed to be accurate, this smolt number estimate suggests an excellent over winter survival.

The 1982 estimated hatchery contribution (17.4%) and survival (10%) were the highest attained, since this project was initiated. The unanswered question is whether hatchery fry stocking has affected natural smolt production in the Tustumena Lake system. From our studies to date, we cannot determine whether hatchery contribution represents an increase in the population or simply a replacement of wild stock. In addition, we recognize that highly variable environmental factors have a great influence over the annual production cycle in Tustumena Lake as in other sockeye salmon nursery areas. We are attempting to answer these questions through a comprehensive program which includes continued smolt monitoring, hydroacoustic surveys, tow net surveys, and limnological research in Tustumena Lake.

ACKNOWLEDGMENTS

The authors would like to express appreciation to the Kasilof Hatchery staff for the excellent job they did of culturing sockeye salmon used for release during this program and for the cooperation they have given us. We would also like to thank seasonal fishery technicians Richard Dederick and Douglas Waring for their help in conducting field work associated with the project.

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Appendix A. Tustumena Lake sockeye salmon fry stocking and marking history, 1976-1982. Dots (...) indicate no fry were released, or none were marked in the release.

Release year	Glacier Flats Creek			Bear Creek			Total		
	Number fry stocked	Number marked RV	Percent	Number fry stocked	Number marked LV	Percent	Number fry stocked	Number marked	Percent
1976	1,138,000	...	...	...	...	...	1,400,000	...	...
1977	...	...	...	...	...	...	...	...	...
1978	400,000	...	...	...	...	...	400,000	...	...
1979	4,860,000	30,500	0.62	2,900,000	36,100	1.24	7,770,000	66,600	0.86
1980	2,710,000	32,700	1.20	2,500,000	32,800	1.31	5,210,000	65,400	1.26
1981	4,970,000	198,000	3.99	3,810,000	254,000	6.67	8,780,000	452,000	5.15
1982	8,300,000	210,000	2.53	7,650,000	249,000	3.25	15,950,000	459,000	2.88

Appendix B. Kasilof River discharge in m^3/s, 1982. Dots (...) indicate no data collected.

Date	U.S.G.S. bridge gauge	ADF&G Gurley meter
5/04	16.2	...
5/26	17.8	...
5/27	...	13.3
6/02	19.0	...
6/03	...	23.3
6/10	27.2	28.2
6/16	29.3	...
6/17	...	32.3
6/23	36.8	...
7/01	49.2	...
7/05	...	52.3
7/08	62.6	...
7/14	79.7	...

APPENDIX C

Deriviation of the formula for estimating the variance of the number of migrating smolt in an age class.

by Kit Rawson, F.R.E.D. Division, Anchorage

In the Kasilof River smolt project daily scale samples are taken to estimate the age composition of the migrating smolts. At the same time the total population is estimated using the dye marking method, as discussed in the body of this report.

This appendix discusses how to combine these estimates to get an estimate, with a confidence interval, of the number of smolts in each age class.

The following notation will be employed:

$\hat{N}$ estimated total smolt migration for the week

$\hat{N}_k$ estimated migration of age k smolts (k = 1 or 2).

$\hat{P}_k$ estimated proportion of the run that is age k

m sample size for age class estimation

M_k number of fish in the sample that are age k.

The formulas for $\hat{N}$ and its variance, Var $(\hat{N})$, are given by Rawson (1982) and in the body of this report. The formulas for $\hat{P}_k$ and its variance are well known (e.g, Fleiss, 1981), and they are:

$$\hat{P}_k = M_k/m$$

$$\text{Var}\ (\hat{P}_k) = \hat{P_k}\ (1 - \hat{P_k})/m$$

$$= [M_k\ (m - M_k)]/m^3$$

One assumption is necessary in order to combine $\hat{P}_k$ and $\hat{N}$ to get an estimate of $\hat{N}_k$, namely that $\hat{P}_k$ and $\hat{N}$ are independent. In the Kasilof smolt project this assumption is valid.

Now, a logical (and unbiased under the assumption of independence) estimate of N_k is:

$$\hat{N}_k = \hat{P}_k \hat{N}$$

The formula for the variance of a product of independent random variables may be found in many statistics books. From the formula we obtain:

$$\text{Var}(\hat{N}_k) = \hat{N}^2 \text{Var}(\hat{P}_k) + \hat{P}_k^2 \text{Var}(\hat{N}) + \text{Var}(\hat{P}_k) \text{Var}(\hat{N})$$

Formulas for all of the components of the right hand side of this equation are contained in the body of this report or in this appendix.

If we can assume a normal distribution for $\hat{N}_k$ then a 95% confidence interval for $\hat{N}_k$ can be easily determined from the above variance formula.