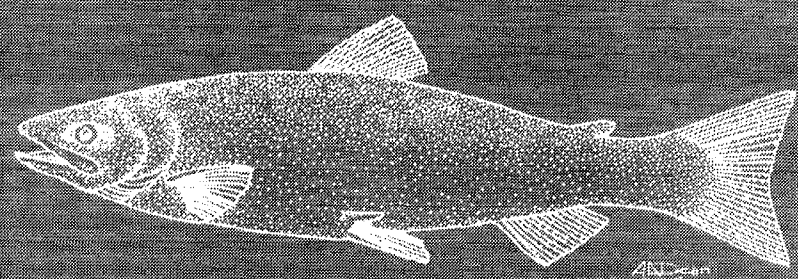
Crescent Lake Sockeye Salmon Smolt Evaluation Activities, 1992-93



By

M. Scott Kelley
and
Ronald P. Josephson

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
Southeast Region
Juneau, Alaska

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ABSTRACT

Three hatchery stocking techniques (unfed fry, pre-smolts, and smolts) were evaluated for sockeye salmon (*Oncorhynchus nerka*) at Crescent Lake near Juneau, Alaska. In addition, basic information was collected on smolt size and age composition for sockeye salmon emigrating from Crescent Lake in 1992 and 1993. Spring fry to smolt survival of 1991 brood year fish stocked as unfed fry was 0.3%. For 1991 brood fish stocked as pre-smolts, survival was 29.0% over the winter. Results of smolt stocking will not be available until they return as adults. Based on a mark-recapture abundance estimate, a total of 463,234 (95% C.I. 228,594 to 697,874) smolts emigrated from Crescent Lake in 1993.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, unfed fry, pre-smolt, smolt, mark-recapture

INTRODUCTION

Crescent Lake is located approximately 40 miles south of Juneau, Alaska. The lake is classified as semi-glacial by the Alaska Department of Fish and Game Limnology Section. The outlet stream empties into the Whiting River approximately 15 miles upriver from Gilbert Bay in Port Snettisham (Figure 1). The Crescent Lake outlet stream is approximately 1.5 miles long and 300 feet wide at its widest point. Depth varies greatly between sections of the creek and because of seasonal water level fluctuations.

Concerns over low escapements of sockeye salmon, *Oncorhynchus nerka*, to Crescent Lake led to efforts to rehabilitate the lake using hatchery back-plants of juveniles. Weir counts from 1983 to 1989 demonstrated an apparent downward trend in escapement to the lake (Table 1). Mark-recapture studies conducted in 1991 (McGregor and Bergander 1993) and 1992 (McGregor and Bergander unpublished data), however, showed that weir counts were not accurate and did not the reflect total escapement; fish were passing the weir undetected. Uncertainty now exists regarding the accuracy of the weir counts and the actual escapements to the lake prior to 1991. The concerns which led to hatchery activities may not have been valid in retrospect. Based on weir counts, the Crescent Lake stock of sockeye salmon did appear to be declining and steps were taken to mitigate that decline. In 1989, adult sockeye salmon were captured in the lake and spawned, the eggs from these activities were incubated at the Department's Snettisham Hatchery. Resultant unfed fry were planted back into Crescent Lake the following spring. Unfed fry resulting from eggs collected at Crescent Lake in 1990 and 1991 were also stocked into Crescent Lake. Unfed fry planted into the lake were otolith-marked with thermal bands during incubation; a unique band was applied for each brood year (Hagen 1993). A summary of Crescent Lake Snettisham Hatchery-related enhancement activities is presented in Table 2.

The second method of lake stocking used to rehabilitate Crescent Lake was pre-smolt stocking. Pre-smolts were reared until late October or early November at the hatchery and then planted into the lake. This technique was used for brood years 1990 and 1991. Pre-smolts planted in 1991 were 100% coded-wire tagged because they had the same thermal mark as unfed fry of that brood. Pre-smolts planted in 1992 were otolith-marked and not coded-wire tagged.

The third method of lake stocking which was tested was hatchery smolt planting. A portion of the 1991 brood was retained and released at the smolt stage. The fish were 100% coded-wire tagged and planted in May, 1993. They share the same thermal mark as pre-smolts of that brood.

Other studies which have been conducted at Crescent Lake included limnological assessment of the zooplankton population structure and abundance and physical properties of the lake. These activities were conducted by the ADF&G Limnological Section and were conducted during monthly sampling trips. Results of these investigations have not yet been published.

Department survival assumptions for lake-stocked sockeye juveniles are 30% for spring fry to fall pre-smolts, and 70% fall pre-smolts to spring smolts. Based on these assumptions, we assume that, in terms of production, one hatchery pre-smolt is equal to approximately three unfed fry. This relationship has important implications for stocking programs and broodstock utilization. If planting pre-smolts is a more effective enhancement tool than unfed fry plants, we could modify current stocking requirements by planting pre-smolts, and thus free up eggs for use in other enhancement projects. Smolts may prove to be even more effective.

To test the effectiveness of our stocking procedures, smolt evaluation studies were conducted at Crescent Lake in 1992 and 1993. Project objectives in both years were to: 1) sample sockeye salmon smolts emigrating from Crescent Lake to determine the percent composition, by age, of wild, hatchery unfed fry, and hatchery pre-smolts; 2) to determine average weight and length, by age, of wild smolts, hatchery unfed fry, and hatchery pre-smolts; and 3) to determine emigration timing. In 1993 we had an additional objective to determine the magnitude of the sockeye salmon smolt emigration using mark-recapture methods.

In 1992 sockeye salmon smolts emigrating from Crescent Lake could have come from three basic groups: 1) age-1.0 and -2.0 wild fry, 2) age-1.0 and -2.0 hatchery-stocked unfed fry, and 3) age-1.0 hatchery stocked pre-smolts. Crescent Lake sockeye salmon smolts emigrating in 1993 could come from four basic groups: 1) age-1.0 and -2.0 wild fry, 2) age-1.0 and -2.0 hatchery unfed fry, 3) age-1.0 and -2.0 hatchery pre-smolts, and 4) age-1.0 hatchery smolts.

Smolt sampling efforts in 1992 were limited to two overnight "grab" samples during the emigration. A more thorough project was carried out in 1993. This report summarizes Crescent Lake sockeye salmon smolt studies conducted in 1992 and 1993.

METHODS AND MATERIALS

Based on results of previous sockeye salmon smolt emigration studies conducted at Speel and Sweetheart lakes, we assumed that smolt emigration at Crescent Lake would begin in mid-May and continue through the end of June. In 1992 smolts were collected with a fyke net fished overnight on May 26-27 and June 2-3. In 1993 the fyke net was fished continuously during the sampling period May 17 - June 22.

A 1/4-inch mesh fyke net with a live box attached was used to capture emigrant fish. The net opening is 4' x 4' with 6' wings attached. During sampling the width of the opening, including wings, was 15 ft. This net had proven very effective for smolt sampling in the past. It is very portable and can be moved with little effort. The sampling location was approximately 0.4 mile downstream in the outlet of Crescent Lake (Figure 2). The stream is at its widest here and there is an island which separates the river into two

channels. The main channel is approximately 157 ft wide and the secondary channel approximately 97 ft wide. Average depth ranges from 36-48 inches, with considerable seasonal variation. Current velocity and stream area data was collected on June 15 at the sampling site for determination of total flow (Newbury and Gaboury 1993) and percent of flow sampled.

For the 1992 sampling dates, the fyke net was in place and fishing by 1830h and was pulled by 0530h the following morning. A sampling goal of 500 smolts, 250 per night, was established in 1992. Smolts were sampled for length and weight at irregular intervals, in blocks of 50 fish, if possible, in an attempt to randomize the samples. Sampled fish were also closely examined for presence of the adipose fin. Fish which were not sampled were enumerated, examined for presence of an adipose fin, and released. After sampling, each fish was placed in an individual sample bottle and preserved in 90% ethanol for later otolith examination to determine the contribution of enhanced smolts to the emigration. Otolith examination was conducted by personnel at the CFMD Otolith Laboratory in Juneau.

In 1993 a sampling goal of 500 smolts representative of the entire emigration was again established. It was assumed that approximately 7,500 smolts would be captured in the fyke net during the fishing period. To meet the 500 smolt sampling goal every fifteenth smolt captured was retained and sampled. Sample procedures were the same as in 1992. Otoliths were examined by the CFMD Otolith Laboratory to estimate the proportion of enhanced fish in the emigration.

In 1993 mark-recapture experiments were conducted to obtain an estimate of fyke net efficiency, which was used to expand net catches to estimate total emigration. A total of six marking experiments were conducted. Fish were marked using three different techniques: Bismark Brown immersion dye, a Panjet™ pneumatic dye injector, and caudal fin clipping. The target number to be marked for each trial was 250 fish. Of those, 30 were to be held for a minimum of 72 hours to observe mark retention and latent mortality. Fish were collected from 1 - 3 nights, depending upon the magnitude of emigration, to achieve the 250 fish goal. Fish marked for trials 1, 2 and 3 were released at 1320h, 1445h and 1700h, respectively (daylight hours). Fish from trials 4, 5 and 6 were released at 2200h, 0020h and 0000h respectively (nighttime hours). Fish from trial 1 were released approximately 100 meters upstream from the fyke net, at a point where the river has a minimum channel width. All subsequent releases were made approximately 50 meters above the first release site. The release site was changed to allow for more thorough mixing of marked and unmarked fish, the current velocity at the upper location being less than at the lower location. Marked fish were released in roughly equal, small lots at locations across the width of the channel.

An estimate of the total emigration, and the associated variance, for the sampling period was calculated using the methods of Bailey (in Seber 1982):

$$\hat{N} = \frac{D * n}{(d+1)}$$

$$Var\left[\hat{N}\right] = \frac{D^2 * (n + d + 1) * n}{(d+1)^2 (d+2)}$$

where:

$\hat{N}$ = total number of fish migrating past the trap,
n = total number of fish captured in the trap,
D = number of fish marked and released upstream,
d = number of marked fish captured in the downstream trap.

One group of fish which was not sampled for length, weight, scales, or otoliths was the 1991 brood stocked as smolts in 1993. These fish were much larger than the wild, and enhanced pre-smolts and unfed fry smolts. They were also marked with an adipose clip and coded-wire tagged prior to stocking. Because of this, any large (5 to 9 g) adipose-clipped sockeye smolts captured in the fyke net were simply counted and released, they fish did not factor into the mark-recapture estimate.

RESULTS

In 1992, a total of 282 (of 632) and 252 (of 754) sockeye salmon smolts were sampled on May 26-27 and June 2-3, respectively. Average lengths and weights by age and age composition are summarized in Table 3. Based on adipose and otolith examination, 94.1%, 5.1% and 0.8% of the fish sampled at Crescent Lake in 1992 were of wild, hatchery unfed fry, and hatchery pre-smolt origin, respectively. The age-1.0 were very small, below the suggested threshold size for smolting (Koenings and Burkett 1987), with an average weight of age-1.0 wild smolts of 1.3 g and an average length of 54.6 mm. No estimate of the total emigration of sockeye salmon smolts from Crescent Lake in 1992 was possible.

In 1993, a total of 7,594 sockeye salmon smolts was captured. Emigration timing coincided with high flows (Figure 3, Table 4). Results of mark-recapture experiments to determine the proportion of the emigration captured in the fyke net are presented in Table 5. Average estimated recapture efficiency was 1.5 percent. The release site for the first trial at approximately 100 meters above the fyke location was determined to be too close to the fyke net entrance, thus not allowing for marked fish to become randomly mixed with unmarked fish. The results of this trial were discarded. A release location was selected approximately 50 meters upstream, this site was used for all subsequent releases. The final trial was conducted one night prior to the removal of the net. This trial was also disregarded due to lack of adequate fishing time for recapture. No abnormal mortality was observed for fish held after marking. All marks were visible up to 72 hours after marking. Some fading of the Bismark Brown marked fish was apparent after this time.

A Chi-square test for equality showed that the results of the first trial were significantly different than the four subsequent trials (c^2=15.6, 4 d.f.). With the removal of the results of the first trial there were no significant differences (c^2=2.2, 3 d.f.) in the remaining trials, thus allowing for results from trials 2 - 5 to be lumped to obtain one estimate of sampling percent. The fyke was estimated to sample 1.5% of the emigrating sockeye salmon smolts. Using Rawson (1984), an estimated 463,234 (95% C.I. 228,594 to 697,874) sockeye salmon smolts emigrated from Crescent Lake during the sampling period. This estimate did not include the 1991 hatchery smolts planted in 1993. A total of 497 sockeye salmon smolts were sampled for length, weight, scales and otoliths. Average lengths and weights for all classes, wild age-1.0 and -2.0, hatchery pre-smolts and unfed fry, are presented in Table 3. As in 1992, the smolts were quite small wild age-1.0 smolts averaged 1.2 grams and 52.6 mm.

Otolith examination showed the percent contribution of wild and hatchery smolts in the emigration (Table 6). Based on these results, over-winter survivals of pre-smolts, and spring fry to smolt survivals for unfed fry from hatchery plants can be estimated. Unfed fry survivals were quite poor at 0.3%. The pre-smolt survival of 29.0% was also less than our assumption of 70%.

Flow calculations were based on data collected on June 15 (staff gauge height was 245mm, an average level relative to the variation we observed). On that day we estimated the total flow at 663 cubic feet per second (c.f.s.), with main a channel flow of 468 c.f.s. and a secondary channel flow of 195 c.f.s. We estimated that the flow through the fyke net was 32 c.f.s., or 4.8% of the total.

A total of 26, 1991 brood, hatchery smolts were captured in the fyke net. Of these, 16 were captured on the first two nights after release, the rest were scattered over the subsequent eight nights. We believe that the fish were capable of avoiding the fyke net or, if captured, were able to swim back out of the fyke entrance. To determine if the low catch was because fish stayed in the lake, we conducted beach seining operations during the period July 13-15 at several locations within Crescent Lake. A total of 12 sets were made with a 100-foot, 1/4-inch mesh seine. No brood year 1991 sockeye salmon from this release were captured. Several thousand rearing wild sockeye salmon fry were captured, as well as seven age-1.0+ coho salmon.

DISCUSSION

Results of the 1992 work indicated a poorer than expected contribution of hatchery unfed fry and pre-smolts to the smolt emigration. We did, however, collect a large number of smolts during the two sampling efforts in 1992 (632 and 754). As the trap was fished in the same location in 1992 as in 1993, we can infer, in light of our 1993 results, that the 1992 smolt emigration was large. The poor showing of hatchery-stocked fish in these samples indicated that wild production dominated the smolt run. Due to the limited nature of the 1992 samples we were unable to determine whether the low numbers of hatchery-produced smolts was due to

sampling error (i.e., the hatchery fish migrated earlier or later than our sample dates), or poor post-stocking survival. Results in 1993 did not indicate a difference in emigration timing.

The poor survival indications from the 1992 work were confirmed in 1993. Based on the 1993 results, it is clear that unfed fry plants in Crescent Lake are not working. Survival standards for unfed fry stocking are 21% for spring fry to smolt; we obtained an estimate of less than 1% for the 1991 brood year fish. It is possible, but not likely, that a significant number of this brood year held over in Crescent Lake and will emigrate as age-2.0 smolts in 1994. Fry plants in other Southeast Alaska lakes served by Snettisham Hatchery have done well. Sweetheart Lake in S.E. Alaska (Barto and Yanusz, unpublished data), and Tahltan Lake in British Columbia (Pacific Salmon Commission, Report TCTR (94)-1) are examples. We suspect that the low survivals of hatchery-planted unfed fry and pre-smolts at Crescent Lake are due to a low forage base. Results of limnological sampling tend to confirm this suspicion. The seasonal mean macrozooplankton density at Crescent Lake for 1980-1981 and 1987-1990 was 72 mg/m^2, the lowest value of any of the lakes in the Limnology Section survey (Barto and Koenings unpublished draft). These results suggest that Crescent Lake may have a limited rearing potential.

Our over-winter survival estimate for brood year 1991 pre-smolts was 29.0%. This is less than half the 70% assumption of Limnology Section's biostandards based on Koenings and Burkett (1987). Pre-smolts from both the 1990 and 1991 brood years were relatively small, 1.2 and 1.5 g, respectively, at the time of stocking, which probably contributed to reduced survival. Stocking pre-smolts at larger sizes, at or near 3.0 grams, could significantly increase pre-smolt survival. Modifications to Snettisham Hatchery, completed in 1993, may make it possible to achieve larger pre-smolt stocking sizes. Although pre-smolts appear to have lower than expected survival, they were larger than other smolts in their age class and are clearly a better enhancement strategy than unfed fry.

At this time, no inferences regarding the survival or contribution of brood year 1991 fish stocked as smolts from the hatchery can be made. A very low number of these fish were captured in the fyke net. Whether this was due to poor survival, the fish holding over in the lake, or net avoidance, is unknown. Because of high costs associated with rearing fish for an extended period of time, smolt planting may not be a cost-effective enhancement tool. However, the increased size of these fish will likely provide for higher survivals to adult. The effectiveness of this stocking method will be better known after adult returns in 1995 and 1996.

RECOMMENDATIONS

1) Reconsider need to back-plant sockeye to Crescent Lake since gross undercounting biases in past weir counts are suspected. The low weir counts had led to the assessment that the stock was depressed, and was

over exploited, and needed to be rehabilitated. Do not back-plant unfed hatchery fry to Crescent Lake until the causes of poor in-lake survivals of these fish are understood and the relationship between available forage base and sockeye salmon fry densities is better understood.

2) Plant pre-smolts at 3.0 g or larger size.

3) Do not plant hatchery-reared smolts until the adult returns from the first stocking have been evaluated and the effectiveness of this method have been proven.

4) Maintain smolt and adult evaluation efforts at Crescent Lake using at least one overnight sample of smolts during expected emigration. Recover otoliths from adults in the fishery and on the spawning grounds to complete the evaluation of the different treatments.

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Table 1. Annual estimated escapements of adult sockeye salmon to Crescent Lake, 1983-1992.

Year	Estimated Escapement
1983[a]	19,422
1984	6,807
1985	7,249
1986	3,405
1987	7,839
1988	1,199
1989	1,099
1990	1,262
1991[b]	9,355
1992[c]	23,000
Average	8,064

[a] In 1983 the Crescent Lake weir was covered with chicken wire mesh. It is assumed that no adult sockeye salmon passed through the weir unobserved.

[b] McGregor and Bergander 1993.

[c] McGregor and Bergander unpublished data.

Table 2. Summary of Crescent Lake sockeye salmon enhancement activities, 1989-1993.

Brood Year	Eggs Collected	Unfed Fry Stocked	Pre-smolts Stocked	Smolts Stocked
1989	547,054	215,556	0	0
1990	813,298	388,460	69,193[a]	0
1991	986,701	551,556	83,000	66,000[b]
1992	1,585,553[c]	0	0	0
1993	2,635,517[d]	0	0	0
1994	578,000[e]	0	0	0

[a] 100% coded-wire tagged.

[b] 100% coded-wire tagged.

[c] No Crescent Lake stocking from this brood, 767,000 unfed fry to Sweetheart Lake, and 335,000 smolts released in Gilbert Bay.

[d] No Crescent Lake stocking from this brood, 1,740,000 unfed fry to Sweetheart Lake, and 204,000 smolts released in Gilbert Bay.

[e] Projected stocking of 150,000 pre-smolts to Crescent Lake in 1995 and 250,000 smolts in Gilbert Bay in 1996.

Table 3. Summary of average length and weight, and age composition of Crescent Lake sockeye salmon smolts from different treatment groups, 1992-1993. Standard errors in parentheses.

Year	Group	N	Percent Composition	Average Length	Average Weight
1992	wild 1.0	245	90.0%	54.5(0.26)	1.3(0.02)
	wild 2.0	11	4.1%	70.3(1.35)	3.2(0.13)
	unfed fry 1.0	2[a]	0.8%	53.0(n/a)	1.1(n/a)
	unfed fry 2.0	0	-	-	-
	pre-smolt	13	5.1%	56.2(0.82)	1.5(0.08)
1993	wild 1.0	378	80.6%	52.6(0.23)	1.2(0.02)
	wild 2.0	62	13.2%	61.8(0.57)	1.9(0.07)
	unfed fry 1.0	2	0.4%	51.5(1.50)	1.1(0.15)
	unfed fry 2.0	3	0.6%	57.3(2.40)	1.4(0.28)
	pre-smolt	25	5.2%	59.2(1.19)	1.8(0.13)

[a] The otolith laboratory examined a sample of 117 smolts. Of those, 1 was a brood year 1990 unfed fry. Sample size of for this group is based on sampling percentage expansion..

Table 4. Daily counts of sockeye and coho salmon smolts and Dolly Varden char captured in the Crescent Lake outlet, 17 May through 22 June, 1993.

Date	Sockeye	Coho	Dolly Varden	River Level(mm)
May 17	4	34	10	375
18	3	58	13	345
19	445	5	2	210
20	458	11	2	350
21	1,075	6	2	540
22	803	7	2	420
23	258	3	1	330
24	454	4	0	290
25	376	6	0	250
26	429	6	0	260
27	189	5	0	280
28	257	0	0	270
29	178	7	0	260
30	166	0	0	280
31	76	4	0	10
June 1	121	18	0	330
2	112	7	0	380
3	88	7	0	320
4	63	2	0	350
5	117	3	0	445
6	346	16	0	615
7	727	16	0	480
8	263	10	0	230
9	67	8	0	112
10	22	3	0	46
11	88	14	0	70
12	63	9	0	40
13	35	4	0	110
14	33	0	0	130
15	39	5	0	250
16	5	3	0	310
17	73	4	0	400
18	77	5	0	340
19	50	5	0	220
20	28	10	0	130
21	3	2	0	80
Totals	7,594	307	32	
Mean	211	9	1	282
Variance	62,194	112	7	18,237

Table 5. Summary of mark-recapture trial results for Crescent Lake, 1993.

Date of Test	Mark Applied	Total Marked Fish Released	Total Marked Fish Recaptured	Percent Recapture
5/20	BB[a]	218	12[b]	5.5
5/23	Panjet[c]	221	3	1.4
5/29	BB	216	5	2.3
6/03	UC[d]	219	2	0.9
6/07	LC[e]	198	3	1.5
6/20	LC	152	0[f]	0

[a] Bismark Brown mark.

[b] These fish were released at a location which, after consideration, was determined to be too close to the fyke net. Results of this test were not included in mark-recapture estimate. Subsequent releases were made at a location upstream from this release site.

[c] Panjet mark on upper caudal using flame red paint mixture.

[d] Upper caudal clip.

[e] Lower Caudal clip.

[f] Results of this test were not included in mark-recapture estimate. The trap was pulled before an adequate recapture period had elapsed.

Table 6. Contribution of wild and hatchery sockeye salmon smolts to the 1993 Crescent Lake emigration, based on otolith results expanded by total population estimates from mark/recapture experiments.

Group	Percent of Emigration	Estimated Number In Emigration	Estimated In-lake Survival
wild 1.0	80.6%	373,367	-
wild 2.0	13.2%	61,147	-
pre-smolt[a]	5.2%	24,088	29.0%
unfed fry 1.0[a]	0.4%	1,853	0.3%
unfed fry 2.0[b]	0.6%	2,779	-
	Total	463,234	

[a] From brood year 1991.

[b] From brood year 1990.

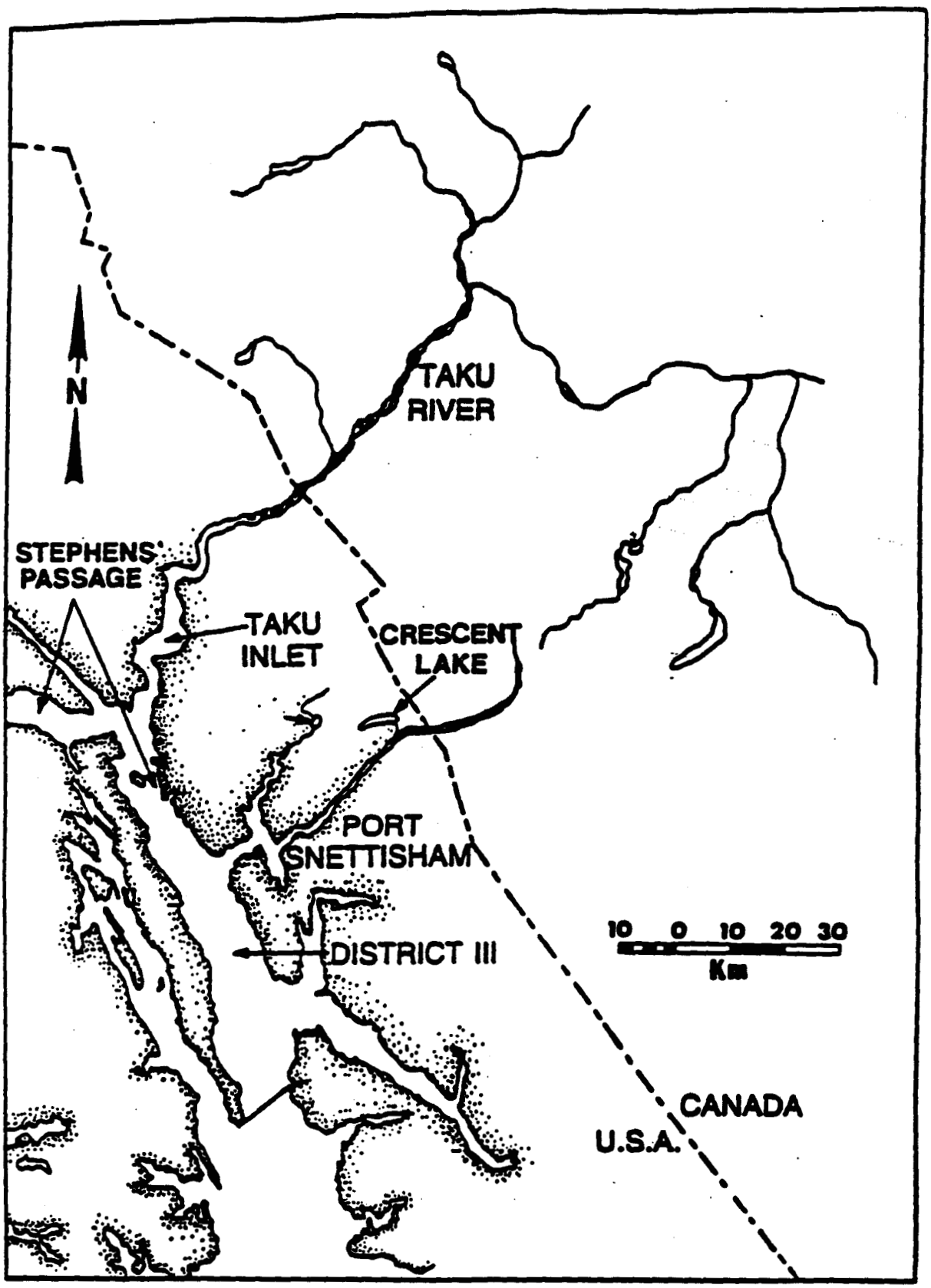

Figure 1. Crescent Lake and adjacent fishing areas.

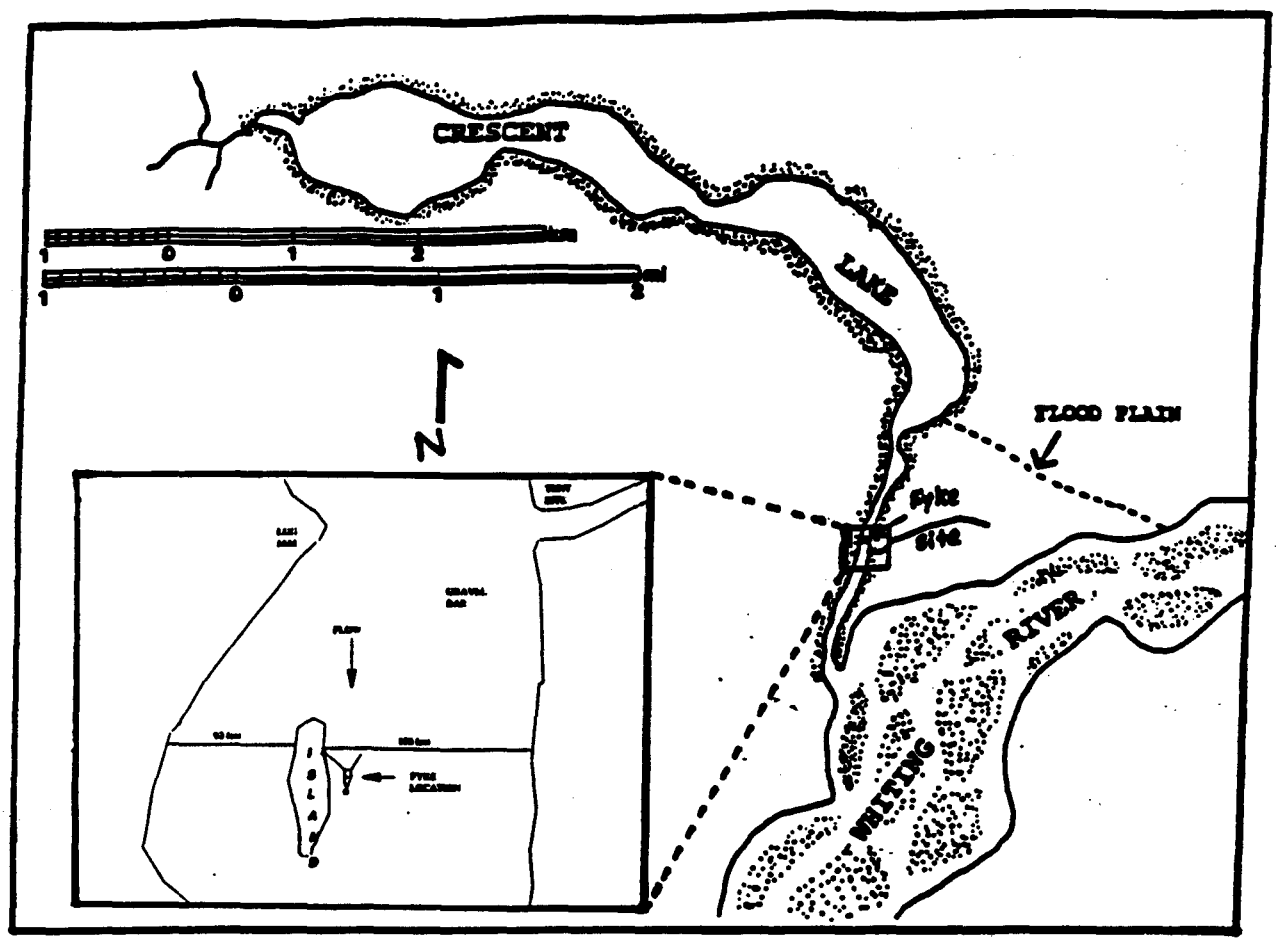

Figure 2. Location of the fyke net site on the outlet stream of Crescent Lake.

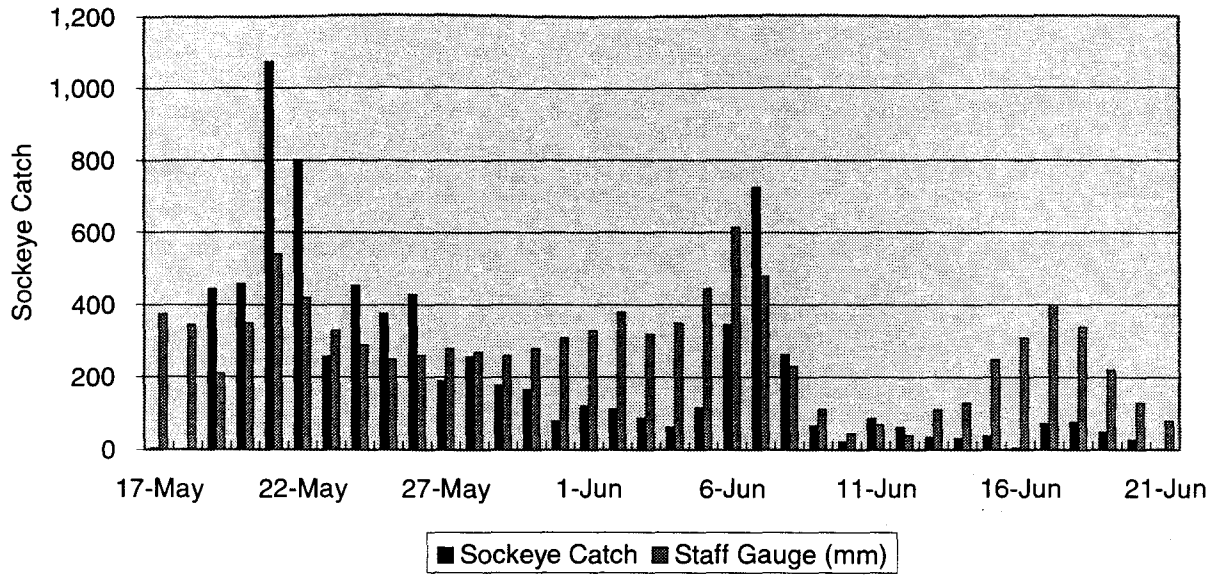

Figure 3. Daily catch of sockeye salmon smolts and staff gauge measurement of river height, Crescent Lake outlet, 1993.